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Forest Products Research 1957

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FOREST PRODUCTS RESEARCH 1957

Report of the Forest Products Research Board with the Report of the Director of Forest Products Research

LONDON
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1958

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1957

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR 1957

To The Council for Scientific and Industrial Research

We, the Forest Products Research Board beg leave to present our report for the year ending December 31st, 1957. We have met on four occasions.

We have considered and approved the Director's report, which is appended hereto. On the occasion of our meetings at the Laboratory we have inspected the work in progress in various Sections. We are satisfied that the high standard of research, both basic and applied, has been fully maintained during the year and that the best possible service has been rendered to industry, other institutions and the public. We are satisfied, also, as to the general scope of the programme and the distribution of effort among the various fields of research.

In matters of policy our attention has been turned to two main subjects—the proposed transfer of the responsibility for some of the Laboratory's work to the Timber Development Association, and the programme for the coming five-year period. In regard to the former, we have endorsed the proposals for transfer, and have considered their effect upon the programme for the coming year. The implementation of the proposals, which will be spread over a period, requires that the Laboratory's programme for 1958/9 shall be flexible enough to complete the smooth changeover, and shall allow for the putting in hand of new research projects as staff are progressively liberated. We have discussed with the Director his proposals to effect this, and have recommended approval of the programme which he has submitted for the coming year.

For the next five-year period, we have surveyed the main fields of the Laboratory's work and have discussed them with the Director and the heads of Sections. The proposed programme allows for a considerable increase in the work on home-grown timbers for the Forestry Commission, and for new work in the existing fields. This will be progressively of a more fundamental type and will allow for new developments such as research in the pulping of home-grown timbers.

While we are agreed that in the light of prospective developments it is right that the emphasis of the Laboratory's work should increasingly be laid on work of a more basic and forward looking type, we do not forget that all forest products research has an industrial objective, and should ultimately result in the more efficient and economical use of wood. In our continuing review of the details of the programme we shall take care to see that the research work does not become too far abstracted and divorced from its possible industrial outcome.

MEMBERSHIP OF THE BOARD

On completion of their periods of membership Sir Edward Monkhouse and Mr. H. A. Collinson retired from the Board in March, 1957. We wish to acknowledge the valuable service they have rendered to the Laboratory. Mr. W. Hardy,

Ministry of Supply Assessor, and Mr. W. Abnett, Ministry of Works Assessor, also retired in March, 1957. We wish to record our thanks to Mr. Hardy not only for his services to the Board, but also for his long personal interest in the Laboratory.

We welcome to the Board Sir Bernard Keen, Professor H. C. H. Gurney, and Mr. Donald Murray as new members, and Sir Arthur Gosling on his re-appointment as Official Member for the Forestry Commission. Mr. O. P. D. Williams replaces Mr. Abnett.

R. G. Bennett,
Chairman

January, 1958

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR 1957

Introduction

During 1957 there has been no major change in the scope or orientation of the Laboratory's work. There has, however, again been a slight increase in the amount of basic research, and a slight reduction in the advisory work. The testing and evaluation of exotic timbers and of home-grown species has continued and the general pattern of the research work has closely followed that of the previous year.

General

STAFF, BUILDINGS AND EQUIPMENT

The structure and proportion of the staff complement have remained essentially the same as in 1956, and no major additions or alterations have been made to the Laboratory's buildings or its equipment.

TOURS ABROAD

The Officer-in-Charge, Chemistry Section, attended the International Consultation on Insulation Board, Hardboard and Particle Board held at Geneva in January-February, 1957. The Consultation was a meeting of experts from 36 countries, called together to exchange views and to prepare an authoritative report on all aspects of the production, application and marketing of these materials.

At the end of April three officers attended the Hanover Machinery Fair, Germany, to study developments and obtain up-to-date information on the machinery employed in the wood-using industries.

An officer of the West African Timber Borer Research Unit, who is stationed at the Laboratory, visited the Bundesforschungsanstalt für Forst-und Holzwirtschaft, Reinbek, Hamburg, during May to study the transmission of fungi by ambrosia beetles. Field work was carried out in the Sachsenwald, and entomologists in Hamburg were visited.

During August and September the Director visited Australia to attend the Seventh British Commonwealth Forestry Conference, which was held this time in Australia and New Zealand. A preliminary conference of the forest products research delegates took place in Melbourne, where the work of the Commonwealth laboratories during the past five years was discussed, and plans made for the continuation of co-operation, especially of the corresponding committees and the translation services. The Director then attended that part of the main conference which was held in Australia. The earlier sessions were held in Adelaide, and the later ones in Canberra.

Between conference meetings, a comprehensive tour was made of Tasmania, South Australia, Victoria, New South Wales and Queensland; in all these states the forests and a wide range of mills and plants were visited. To the Australian Government and the individual members of all the forest services thanks are due for the excellent arrangements and great hospitality, which ensured the success of the visit.

LIAISON AND COLLABORATION

Collaboration with professional institutions and other laboratories has been maintained. During the year joint projects have included work on the preservation of marine timbers (Institution of Civil Engineers), of sleepers (British Railways) and of transmission poles (British Electrical and Allied Industries Research Association, electricity area boards and the General Post Office); on cooling towers (Central Electricity Authority); the metabolic products of wood-rotting fungi (London School of Hygiene and Tropical Medicine); the biology of timber-boring insects (Colonial Office, forest departments, and research institutions); the infestation of logs (West African Timber Borer Research Unit); the structure of the hemicelluloses (University of Edinburgh); the production of hardboards from tropical timbers (Colonial Products Council); the effect of gamma rays on the hygroscopicity of wood, the treatment of insect infestation by irradiation, and the use of isotope radiation for measuring the density of wood samples (Atomic Energy Research Establishment, Harwell). The durability tests on plywood for marine craft continue at H.M.S. *Hornet*.

There have been two meetings each of the Adhesive Makers' Panel and the Plywood Research Panel to discuss the Composite Wood research programme. Thanks are again due to the associations and the individual members of the panels for their unstinted and valuable assistance.

Close liaison has been maintained with industry, and members of the staff continue to serve on various technical and advisory committees.

ADVISORY SERVICE

This work has been carried on by the usual methods of visits and visitors, written replies, reports and answers by telephone. For the many enquiries of a routine nature the standard leaflets issued free by the Laboratory have continued to carry information to many thousands of people. The number of enquiries answered by letter during the year was 4659; the number of leaflets issued to the public directly or at exhibitions was 31,690.

PUBLICATIONS AND RECORDS

During the year six new priced publications were issued through H.M. Stationery Office, comprising the Annual Report for 1956; "A Handbook of Softwoods"; *Special Report* No. 12 "The Effect of Depth on the Strength Properties of Timber Beams, with an Analysis of the Stresses and Strains Developed"; and three bulletins. The Handbook describes the properties and uses of 54 coniferous species, with recommendations of suitable saw teeth, cutting angles and kiln-drying schedules, and descriptions of the trees and their natural distribution. *Bulletin* No. 39 forms Part 3 of the series on "The Strength Properties of Plywood" and deals with the influence of the adhesive on the strength of plywood. *Bulletin* No. 40 "Timbers for Flooring" gives a history of the abrasion testing

of timber and classifies the numerous species investigated, according to their wearing properties and suitability for the various types of floor. *Bulletin* No. 41 "The Strength of Nailed Joints" describes tests on the dependence of joint strength on the number and diameter of the nails, the thickness, specific gravity and moisture content of the members, and the direction of loading relative to the grain of the wood, the nails being driven perpendicularly into the side grain of the wood. From the results and the empirical equations developed, permissible lateral loads applicable to various softwood species are derived for the nails tested. *Record* No. 21 "The Growth and Structure of Wood", reprinted several times with minor amendments since 1937, was thoroughly revised and issued in a second edition. The text book "Decay of Timber and Its Prevention" has also been fully revised; much new matter and many new references have been incorporated. The revision has been submitted for publication. In addition to the above, four leaflets were revised and 20 papers published in the scientific and technical press. Particulars of these are given in Appendix II.

The various reports prepared for limited circulation numbered 29, including 14 on the subject of plywood.

Programme of Research

WOOD STRUCTURE

STUDIES IN COMPARATIVE ANATOMY

Systematic studies of the wood anatomy of a number of natural groups have been continued, notably in the families Dipterocarpaceae and Leguminosae. The results of such work help to perfect botanical classification and provide the essential basis for the identification of timbers. Closely allied species of trees sometimes exhibit important differences in the properties of their timbers and it is therefore desirable to find practical means of distinguishing them.

The activity of foresters in Sarawak, Brunei and North Borneo has provided valuable additional material of the Dipterocarpaceae. Recent work on the structure of these important timbers has thrown light on the systematic position of certain imperfectly known species being studied by the Forest Botanist, North Borneo.

In the Leguminosae the acquisition of new material has enabled a paper on the classification and identification of *Piptadenia* and allied genera to be completed[1]. Following general laboratory tests on a consignment of sepetir (*Pseudosindora palustris*) from Sarawak, a comprehensive study of sepetir and allied species has shown that, on anatomical grounds, there are good reasons for maintaining *Pseudosindora* as a distinct genus from *Sindora* and *Copaifera*.

IDENTIFICATION OF TIMBERS

Steady progress has been made in revising the Laboratory's microscope key to the identification of hardwoods. In many cases means have been found of separating timbers previously regarded as indistinguishable. The diagnostic value of crystalline deposits in woody tissues has been demonstrated in a number of widely separated groups.

Research on the softwoods (Coniferae) has included critical anatomical studies of Ocote pine (*Pinus oocarpa*), a relatively new species imported from Central America, and allied timbers of the pitch pine group, and of the family Podocarpaceae.

COLLECTION OF TIMBER SPECIMENS

The important work of maintaining the Laboratory's reference collection of timber specimens has been continued. Nearly five hundred specimens have been incorporated during the year and a somewhat larger number of duplicates distributed in exchange, not counting some seven hundred microscope slides of wood sections handed over to the Timber Development Association.

In addition to standing arrangements with other timber research organizations, exchanges of mutual benefit have been made for the first time with the Instituto Nazionale del Legno, Florence, Italy; the Universidad de los Andes, Merida, Venezuela; the Administration de Bosques, Ministerio de Agricultura y Canaderia, Buenos Aires, Argentine Republic; and the Botanical Institute, Wroclaw, Poland. Thanks are due also to the forest departments of Brunei, Fiji, Nigeria, Pakistan, Tanganyika and Thailand and to correspondents in other parts of the world for their valued co-operation.

STRUCTURE OF WOOD IN RELATION TO THE PROPERTIES OF PULP

With the increasing use of wood for paper, fibreboard, hardboard and chipboard, demands have been made on the Laboratory for anatomical investigations to assess the prima facie suitability of various timbers for these purposes and to account for difficulties arising in manufacture. Problems dealt with during the year have included damage caused to fibres under certain conditions of chipping, the incidence of colouring matter in Sitka spruce and its effect on paper produced from this species, the fibre characteristics of various species of oak and the marked differences in pulping quality between certain species of dense tropical hardwood. Some time has been spent on developing techniques for the preliminary appraisal of timbers for pulp, involving anatomical and biometric methods, and an investigation of a tropical light hardwood with possibilities as a source of pulpwood has been carried out. In view of the increasing quantities of home-grown timber becoming available for paper and other pulp products it is expected that further research on the anatomical basis for the technical properties of pulp may have to be undertaken.

RATE OF GROWTH AND QUALITY IN HOME-GROWN SOFTWOODS

The work on the relation between rate of growth and density has been continued with particular reference to fairly wide-ringed Douglas fir and Corsican pine grown in the south of England[2]. This material has permitted direct comparisons in respect of density between wood formed early in the life of the tree and that of similar ring-width formed later. In all cases the latter was the denser, indicating that the higher density of older wood is largely due to an age effect rather than to the usual falling off in ring-width which is a normal feature in most trees and has led to the belief that density is closely related to ring-width.

The data for a consignment of Douglas fir from South Devon, classified according to age and ring-width, are plotted in Fig. 1, to show the radial variation in density at each ring-width; the density figures represent the mean values for each ring-width/age group. The dotted curve, based on the mean density for each age group taking all ring-widths together, serves to show the general form of the density variation with distance (in rings) from the pith in the mid-bole timber from these six trees. The curves demonstrate the marked

increase in density which occurred during the first 20 years or so, and the tendency, in this consignment, for density to decrease appreciably beyond about 35 rings from the pith. It was not possible to obtain data for all the ring-width classes throughout the whole period of growth covered by the six trees, but the age sequences at each ring-width suffice to give a fair idea of the general trends. No significant relationship between ring-width and density is evident.

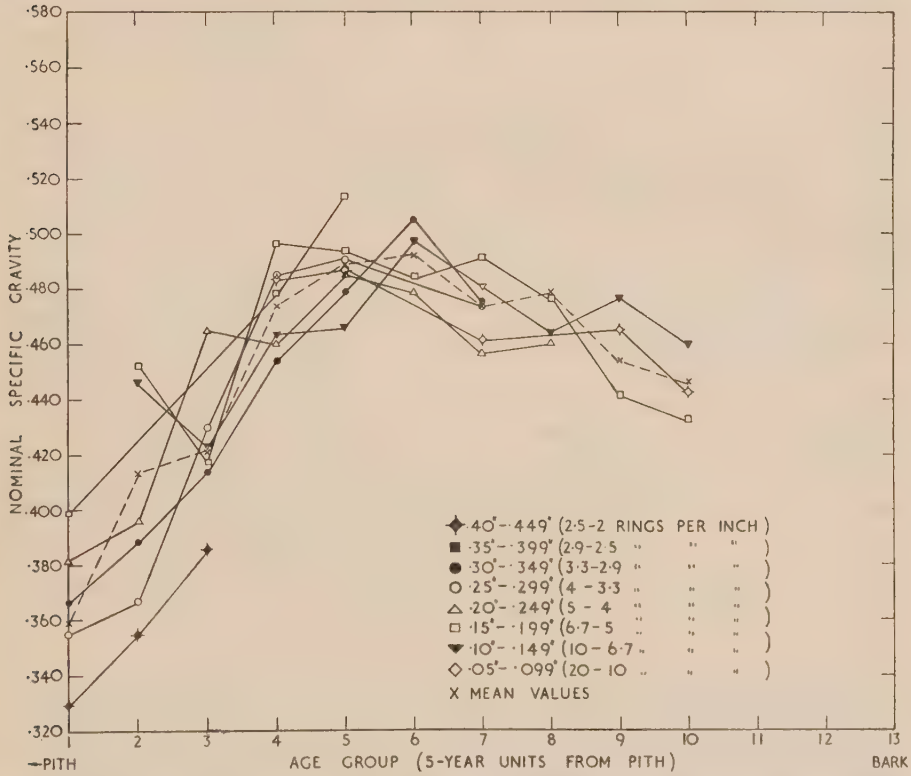


Fig. 1. Douglas Fir (*Pseudotsuga taxifolia*) from Dartington, Devon: relation between ring-age and density at constant ring-width

The curves for Corsican pine from the Forest of Bere, Hampshire, (Fig. 2) differ in certain respects from the corresponding curves for Douglas fir (Fig. 1). The marked increase in density with age is clearly demonstrated but this approximates more closely to a straight-line relationship than was the case in Douglas fir, with no indication that a maximum density has been attained despite the greater age of the trees. There is, however, some indication that ring-width has some relation to density; at a given age density tends to increase with diminishing ring-width.

In addition to these two consignments of Douglas fir and Corsican pine, several specimens of these species from other sources, as well as material of Scots pine, European spruce and silver fir, have yielded comparable samples having similar ring-width at different ages. In all cases they have shown a marked influence of age on density.

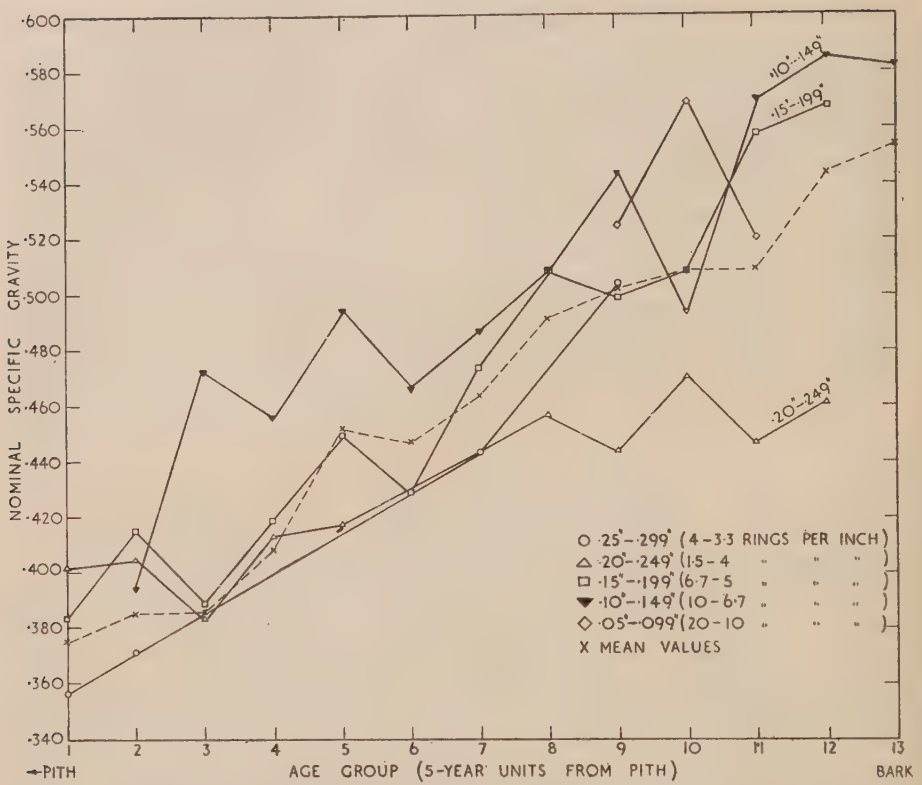


Fig. 2. Corsican Pine (*Pinus nigra* var. *calabrica*) from Forest of Bere, Hampshire: relation between ring-age and density at constant ring-width

A NEW METHOD OF DETERMINING THE DENSITY OF WOOD SAMPLES

The determination of density on numerous small samples, as required for growth/quality investigations, is a time-consuming operation and some attention has been given to developing a more rapid method applicable to small samples such as increment cores. The possibility of using isotope radiation absorption as the means of measuring density has been examined and, with the co-operation of the Isotope Division of the Atomic Energy Research Establishment at Harwell, preliminary tests have been carried out using a specially designed β-radiation source of high intensity. The results show considerable promise. The method is evidently sensitive and it should be practicable to arrange for the variation in density within the individual growth rings of an increment core to be recorded automatically. Furthermore, the use of increment cores should enable a much larger number of trees to be sampled than is possible with traditional methods of stem analysis.

GLOSSARY OF TERMS

In the last three years much time has been devoted, in co-operation with other specialists in this country and overseas, to preparing a new glossary of terms used in wood anatomy, sponsored by the International Association of Wood Anatomists. This has now been published[3].

BRITISH COMMONWEALTH FOREST TERMINOLOGY

It is appropriate to record that Part II of the British Commonwealth Forest Terminology, covering terms used in utilization and forest products research, was published by the Empire Forestry Association[4] during the year and was presented to the Seventh British Commonwealth Forestry Conference meeting in Australia and New Zealand. The Laboratory has made substantial contributions to this work which will be of value in standardizing technical terms and in promoting co-operation between forest products research workers in different parts of the world.

ADVISORY WORK IN WOOD STRUCTURE

As usual many of the enquiries received have been fairly straightforward questions involving the identification of commercial timbers or the provision of information which is available in standard works of reference or in the Laboratory's records. The field is by no means restricted to timbers of current commercial importance, however. The Laboratory is widely recognized as a source of authoritative information on world timbers, as shown by the steady stream of enquiries about obscure foreign species. Enquiries of this kind have had to do both with the possibilities of trade development and with local problems of utilization.

Anatomical examination of wood specimens taken from imperfectly known trees has helped to elucidate their botanical classification, and the identification of the timber of packing-cases damaged by insects has enabled the identity of the insects and the source of infestation to be established.

The number of external enquiries involving a written reply amounted to 523. More than 1100 samples of timber have been identified.

SEASONING

KILNS AND KILN SEASONING

The seasoning properties of a number of species have been examined during the year and the large kilns have been used for seasoning consignments of sapele, poplar, Japanese oak, afrormosia and English walnut. No great difficulty was experienced in drying any of these loads satisfactorily. In addition, a number of glued teak frames 1-in. thick, required for the construction of a wind tunnel by the Royal Aircraft Establishment, Bedford, were successfully dried to the low moisture content value of 5 per cent.

In the test series on the seasoning properties of home-grown softwoods loads of Scots pine and Douglas fir have been dried. The smaller kilns were used for drying experimental loads of a number of species including East African olive, bosquiea, white star apple and nkobakoba.

KILN DRYING BASKETRY WILLOW

In the traditional processes of air drying and storing basketry willow (*Salix* spp.) considerable losses are sometimes sustained when in unfavourable weather conditions serious mould growth and stain develop. In co-operation with the Rural Industries Bureau tests were undertaken to determine whether willow rods could be dried rapidly and satisfactorily in a timber-drying kiln. The rods stacked for kiln drying are shown in Plate 1.

The results indicated that in a kiln with good air flow and venting sufficient to maintain very low humidities at a temperature of about 70° C the willow rods could be dried in 2-in. layers separated by 1-in. sticks in a matter of 10 to 12 hours.

TESTS ON THE EFFECT OF AIR SPEED ON DRYING RATE

Past work on this research project had demonstrated that the advantage to be gained by changing the direction of flow of air in a kiln at short intervals of time could be considerable if the drying schedule employed were suitably modified.

The two main series of test runs carried out in the past year were designed to study the effects of air speed on the uniformity and speed of drying when the flow of air was caused to alternate every quarter of an hour.

It was found that even at the relatively slow air speed of 3 ft/sec the time lag of the centre of an 8ft pile of 1-in. thick beech on that of the two sides in drying from the green to about 12 per cent moisture content was small. The indications were that a speed of 4 ft/sec should prove to be quite adequate for kilns employed for the drying of such material when the direction of air circulation is reversed at fairly frequent intervals.

Test results obtained from the rapid drying at high temperatures of loads of 1-in. Scots pine were adversely affected by unexpectedly large inherent variations in the drying properties of carefully matched groups of samples. Though no definite conclusions could be arrived at in consequence, there were indications that the optimum speed would nevertheless be little in excess of 5 ft/sec.

KILN DESIGN

A circulatory air system of novel design has been installed in the existing shell of the Laboratory's old double-stack longitudinal-shaft kiln. The system consists essentially of 6-ft diameter fans suspended horizontally between the false ceiling and the roof. Curved metal deflectors have been arranged to cause the air to flow laterally to one side passage or the other according to the direction of rotation of the fans. This arrangement has the advantage of taking up considerably less headroom than a cross-shaft kiln with large fans of more orthodox design; moreover, since the fans are driven on shafts through the roof, there is no need for space to be left at the sides of the kiln to accommodate motors or drives.

Full-scale tests have been carried out to determine the air flow characteristics at three different speeds through a load of timber.

Results of tests made to date have shown that for the expenditure of $1\frac{3}{4}$ h.p. an average air speed of 5 ft/sec can be achieved through a stack of 1-in. timber and that the variation within the whole kiln stack is likely to be about $\pm$ 1 ft/sec when the side passages are 3 ft wide.

At the top fan speed the power demand increased to 6·3 h.p. and an average air speed of 7·5 ft/sec was achieved with an overall range of from 5 to 9 ft/sec.

Narrowing the air inlet side passage to 2 ft had relatively little effect on the speed or the uniformity of the air flow.

MOISTURE-PROOFING EFFICIENCY OF SURFACE COATINGS

Test panels of beech have been prepared and conditioned for use in testing the effectiveness of various surface coatings in preventing the wood absorbing moisture from the air. The efficiencies are measured from a comparison of the

rate of pick-up of moisture of treated panels with that of matched controls. None of the coatings so far tested have proved to be more effective than a good bituminous paint.

DISTORTION EXPERIMENTS

Experiments to determine the effect of mechanical restraint during drying on the distortion and subsequent behaviour of timber samples have been continued. A series of tests on African mahogany has been completed and reported upon in an appendix to the original report, which dealt mainly with work on beech samples. The samples of both species were dried from an initial moisture content of about 20 per cent to a final moisture content of 10 per cent. It was found on release of the clamps at the end of the drying period, that all the samples immediately distorted to some extent. For a period thereafter the distortion increased gradually, without any change in moisture content, until a steady shape was eventually assumed. The final distortion of the restrained samples was considerably less than that of matched control samples, which had been allowed to dry freely. The effect of restraint was proportionately greater with beech than with African mahogany. Restraint was found to be more effective in reducing "cup" than in reducing longitudinal distortion. It also caused greater reduction in distortion when the drying was conducted at a high rather than at a low temperature. An article describing the results so far obtained has been published[5].

Further tests, in which keruing is being employed as the test material, are in progress and samples prepared in the green condition have been included so that the effect of initial moisture content can be examined. The effects of drying temperature, and of exposing the samples for a short period (12 hours) to a temperature of 100° C before removing the restraint, are also being investigated.

MISCELLANEOUS TESTS

In response to requests from industry, special investigations have been carried out on the kiln drying of thick pitch pine for vats and sliced oak for barrel staves. In addition tests have been made to determine how such articles as spirit levels and bowls will behave when subjected to varying air conditions such as might be encountered in this country and abroad.

WOOD BENDING

SOLID BENDING

The steam-bending properties of home-grown ash from a number of localities are being examined and although no very marked differences have been observed the best bending timber so far tested came from a site in South Wales. Data have been obtained on the bending properties of six tropical woods which have included yellow seraya, pillarwood and East African mulberry. The East African mulberry was shown to have steam-bending properties sufficiently good to make it a promising substitute for some of the well known bending timbers such as beech. Unfortunately, it is bright yellow in colour and a yellow liquid exudes when the wood is steamed. It is probable therefore that its appearance rather than its bending qualities may limit its field of application.

The pillarwood was found to bend well but had a marked tendency to split and distort during drying. Large-scale tests have been completed on horse chestnut and European walnut and both species, but in particular the walnut, proved to be very good bending woods.

In experiments carried out to determine how effectively bent pieces could be set to shape by heating and drying in a radio-frequency electrical field it was found that when red heart is present in beech the wood tends to develop internal splits. This was shown by microscopic examination of the timber to be caused by the presence in the red heart of tyloses (Plate 2), which would tend to impede the free egress of steam.

Tests made to determine the reasons for certain bends of solid material fracturing on the convex face in service have led to the conclusion that incipient cracks are induced during the actual bending operation and that an increase in moisture content of the surfaces is responsible for movements which enlarge these fractures.

A new design of hockey stick of sharp radius of curvature has become very popular in recent years and many of these made of Indian mulberry have been imported from Pakistan. The bending properties of home-grown ash do not permit manufacturers in this country to produce bends of so small a radius economically. During the year a method was evolved at the Laboratory whereby the losses occasioned in making such bends from ash could be greatly reduced. It consisted essentially of producing each bend in two separate halves, the halves being then glued together by means of a waterproof resin glue to form the whole (Plate 3A). This process has been demonstrated to manufacturers of sports goods, and playing trials are being made with hockey sticks produced from home-grown ash in the manner described above.

LAMINATED BENDING

The limiting radii of curvature of thin laminae from nine different hardwoods and two softwoods have been determined and a series of tests started to obtain basic data on the bending properties of various thicknesses of Baltic redwood. Data obtained so far show that the ratio of radius of curvature to thickness is not constant over the range of thicknesses tested.

PLYWOOD BENDING

Basic data have been obtained on the influence of various factors in the setting to shape of African mahogany plywood. The significance of the width factor was relatively small but direction of grain had a marked effect on the setting of plywood of this species. Bends in which the grain of the face veneers is normal to the axis of curvature set much more readily than those with the grain of the face veneers in the other direction.

ADVISORY WORK IN SEASONING AND BENDING

In addition to visits made to the Laboratory by kiln owners, manufacturers and others interested in seasoning and bending, some thirty visits have been paid to firms.

The number of enquiries dealt with in Seasoning and Bending has amounted to 750.

TIMBER MECHANICS

THE STRENGTH PROPERTIES OF TIMBER

The tests of home-grown softwoods supplied by the Forestry Commission have continued throughout the year. Strength data have been obtained for Sitka spruce and Scots pine and work is in progress on Douglas fir and Norway spruce.

Strength tests of the Colonial hardwoods, white and yellow seraya, reported as under investigation last year, have been completed, and data for both green and air-dry material are available. Consignments of East African olive and keruing are also being tested.

The special investigation into the strength properties of English ash is continuing. Three consignments of ash from different sites have been investigated and studies of the relationships between the strength data and other properties, such as density and rate of growth, are being made.

STRUCTURAL USE OF TIMBER

Grading and testing in structural sizes of consignments of Douglas fir from Gwydyr in North Wales and the Forest of Dean and of Scots pine from Farnborough in southern England and Banchory in Scotland, all supplied by the Forestry Commission, have been completed.

The Douglas fir joists of the two consignments were similar in density and in strength properties. On the other hand tests on small specimens of the clear wood of both consignments showed that the older Douglas fir from the Forest of Dean was about 10 per cent more dense than the younger Gwydyr material, a difference that was reflected in their respective strength properties. The difference can probably be accounted for by methods of conversion. The joists which were all of the same size, namely 2 in. $\times$ 6 in., contained material of approximately the same age and growth rate from the centre part of the logs, whereas the small specimens reflected the higher density and strength obtained from the outer parts of the older consignment from the Forest of Dean.

The joists of Scots pine taken from the Banchory consignment, although of lower density, were about 20 per cent stronger in static bending than those from the Farnborough area. The difference was not evident in the modulus of elasticity for the two consignments and since it is assumed that knots do not affect this property the difference in bending strength between the two consignments can probably be ascribed to the relatively large knot clusters found in the Farnborough material and is not inherent in the clear material. Tests on small specimens of clear wood showed the Banchory material to be less dense and less strong than the Farnborough consignment.

As stated in last year's Report (p. 15) a method has been developed for the derivation of working stresses for structural softwoods using data obtained from the tests carried out on small clear test pieces. A few hardwoods have also been used for structural purposes and there is, in consequence, a demand for working stresses for these species. As a first step to meet this demand, data from tests on some of the hardwoods most likely to be used for structural purposes have been analysed. The basic stresses derived from the analysis have been published[6].

Tests have been carried out on standard building units constructed from light timber sections and plywood. The units were all 4 ft wide and varied in length from 21 to 36 ft and in depth from 7 to 15$\frac{1}{2}$ in. Each unit consisted of three troughs joined together lengthwise at 16-in. centres, each having timber members at the top and bottom of each trough, with $\frac{5}{16}$ in. thick exterior grade Douglas fir plywood, nailed and glued to these members to form inclined webs. The units were covered on the top with $\frac{3}{8}$ in. thick Douglas fir plywood. The tests were carried out in accordance with the standard procedure developed for

the testing of all prototype structural units. All the four units tested proved satisfactory under design loading and in no instance did the deflection exceed $\frac{1}{400}$ of the span.

A test has also been made, at the request of the designers, on a box beam about 25 ft long, 16 in. deep and 3 in. in thickness. The beam was of similar design to one tested previously; the only difference between the two beams was that the first beam was completely clad on both sides with plywood while the present beam had alternate bays open. Although of adequate strength the latter was appreciably less stiff than the former completely clad beam. Its deflection was about $\frac{1}{180}$ of the span under design loading compared with nearly $\frac{1}{300}$ for the first beam.

Racking tests have also been made to provide data on the relative merits of four different designs of floor panel. The panels tested were approximately 6 ft square.

STRENGTH OF SOFTWOOD PIT-PROPS

A detailed investigation has been begun in co-operation with the Forestry Commission and the National Coal Board to determine the strength of all species of home-grown pit-props. Tests are being made on both the green and the seasoned props and the relationships between sylvicultural features and strength are being examined.

STRENGTH AND VARIABILITY OF IMPORTED SOFTWOODS

The sampling of the most commonly used structural softwoods to provide information on variability and its relation to strength has continued So far data have been obtained for twenty-five consignments of Baltic redwood, five of commercial western hemlock and two of Baltic whitewood. An analysis of the results of the tests on the first twenty consignments of Baltic redwood indicates that the average strength figures previously available were slightly higher than those for the present series of tests. An important feature has been the increased variability of all properties compared with earlier data. This was to be expected in view of the much wider sampling of material.

LONG-TERM LOADING

The long-term loading experiments on the 2 in. square Baltic redwood and Douglas fir beams mentioned in the Report for 1955 (p. 16) have continued. After three years under load some test specimens of both Baltic redwood and Douglas fir were unloaded and, after conditioning, were tested to destruction. In the same way as those tested after one year under load, these specimens showed no loss of strength compared with that of the original controls. Although there was no loss of strength in the beams an increase in deflection over the initial deflection under load of about 95 per cent in the Baltic redwood and 60 per cent in the Douglas fir was recorded. The beams of both species carried the same load, which was, however, a greater percentage of the ultimate strength of the redwood than that of the Douglas fir. The sets of specimens of both species loaded for one year and three years had a permanent set on removal of load which amounted approximately to the creep which had taken place over the duration of load. It was, however, significant to note that both sets of specimens recovered about one-half of their respective permanent sets during conditioning.

The present series of tests have been limited in scope since they provided data for one loading only. Following exploratory tests and the design of special apparatus, an extension to the project has been started to study the creep of timber and its ultimate long-term strength under different loads. The tests will be made under controlled temperature and humidity. Opportunity will also be taken to investigate an assumption that the limit of creep to failure is the point at which timber begins to flow in a plastic manner. This point is said to be well defined and easily determined by a rapid cyclic loading test. The investigation as planned will, in the first instance, be limited to one strength property, static bending, and one humidity, temperature, species and size of specimen. It is proposed to extend the investigation later to cover other arrangements.

STRENGTH OF NAILED JOINTS

A bulletin "The Strength of Nailed Joints" has been prepared for publication[7].

In addition a series of long-term tests has been begun to examine the behaviour of nailed joints under continuously applied constant load. A timber frame has been erected, from which vertical rows of interconnected joints are suspended, under a constant load attached to the lowest joint. Two-member single shear joints and three-member double shear joints of European redwood, Douglas fir, and Norway spruce are being tested under a load corresponding to the permissible load for the particular joints. One set of joints of European redwood is loaded in excess of the permissible load. For comparative purposes similar joints, matched with those under long-term loading, have been loaded to failure in tests of short duration in a testing machine.

STRENGTH OF TIMBER CONNECTOR JOINTS

The results of strength tests carried out on joints of European redwood members made with four sizes of round and four sizes of square toothed-plate timber connectors are being analysed with a view to determining permissible loads for this type of fastening. To provide additional data for this work further tests are being made. Joints of Douglas fir and Norway spruce made with two sizes of toothed-plate connector have been prepared for test and to examine the variation of joint strength with species.

Groups of joints are also being prepared using one size of connector with members of Douglas fir in the green condition and at 18 per cent and 12 per cent moisture contents. These joints will be tested to examine the effect of the moisture condition of the wood on the strength of toothed-plate connector joints.

STRENGTH OF GLUED JOINTS

It was noted in last year's Report (p. 16) that glued joints of three parallel members tested in compression failed at a much higher load than similar joints tested in tension. The average apparent mean shear stress on the glue at failure was 1200 Lb/sq. in. for the compression tests and 575 Lb/sq. in. for the tension tests. Subsequently standard 2-in. shear cubes and block shear glue specimens were cut from the joints to determine respectively the shear strengths of the wood (European redwood) and of the glue films. The average shear strengths from these tests were 1360 Lb/sq. in. for the wood and 940 Lb/sq. in. for the glue films.

Thus these results indicate that the shear strength of the wood or of the glue bond as obtained from small standard or sub-standard tests cannot be used directly in deriving the strength of any glued joint without modifications being made for the geometry of the joint and the direction of loading on it.

STRENGTH OF PLYWOOD

Samples of plywood made from ceiba, keruing and kapur have been tested under the general project for the determination of the strength properties of plywood. In addition, at the request of industry, average strength values have been determined for samples of commercial plywoods made from Douglas fir and Finnish birch.

An analysis of accumulated data on the strength properties of plywood has been completed[8] and working stress values have been derived for eighteen different species of wood that are likely to be used in commercial plywoods.

LAMINATED TIMBER CONSTRUCTION

The first series of tests on a prototype arch of 30 ft span and 16 ft ridge height have been completed. In these tests loads were applied over full span and half span, with the apex pin-jointed and then fixed with bolted splice plates. Pin-joints were used at the springings and are now being replaced by fixed joints of a type commonly used in constructional work. A second series of tests has been planned to obtain a comparison between the actual and calculated performance of the arch under various loading conditions.

EFFECT OF DEPTH ON THE STRENGTH PROPERTIES OF TIMBER BEAMS

The investigation to examine the effect of depth of section on the strength and elastic properties of timber beams, together with an analysis of the stresses and strains developed, has now been completed. A special report[9] has been prepared for publication.

This investigation was mainly of a fundamental character and the maximum beam depth was limited to about 3 inches. A further series on beams ranging in depth up to 10 inches is under consideration.

ANALYSIS OF TIMBER STRUCTURES

The mathematical analysis of stresses in redundant structures involves a considerable amount of arithmetic, which as well as being time consuming is also fraught with possibilities of error. Because of this there has been in recent years a revival of interest in the use of the indirect model method of analysis which is both quick and simple to apply. With this method it has been shown that estimates can be obtained for the forces, moments and deflections in a structure which are in reasonable agreement with values calculated for an ideal material.

One advantage of laminated timber construction is that it enables the cross-section of structural elements to be varied according to the pattern of loads they have to sustain. This tapering is of particular value for the attainment of aesthetic effect and also allows for economy in the use of materials. It does however complicate the analysis and, since timber is neither homogeneous nor perfectly elastic, it is desirable to assess the accuracy and suitability of the

indirect method of analysis when applied to timber structures. An investigation has been started to obtain direct comparisons between the actual performance of a prototype laminated portal frame under various loads and its performance as predicted from model displacements and by calculation.

EFFECT OF REVERSAL OF LOAD ON STRENGTH

Oars, ladders, scaffold planks and aircraft wings can encounter reversals in the direction of loading, any one surface being periodically in tension or compression. Excessive compression stress can result in the buckling of wood fibres and the formation of compression creases, and the presence of these may cause an unsuspected weakening of the timber.

An investigation has been started to examine the effect of such reversals of load on strength. Tests on small beams of noble fir, Sitka spruce and Douglas fir have shown that under impact load the presence of compression creases in the tension or convex region severely reduces strength. Under gradually applied loads, however, compression creases whether present in the tension or compression regions of a beam had no significant effect on strength. Tests at intermediate rates of loading are planned and the investigation is continuing.

EFFECT OF TEMPERATURE ON THE STRENGTH PROPERTIES OF TIMBER

An investigation has been started to examine the effect of temperature on certain strength properties of timber.

A double-walled testing chamber has been constructed within an insulated cabinet for mounting on the table of a testing machine. Special loading attachments and supports passing through the base and the top of the chamber enable strength tests to be made within the inner chamber.

In the first instance tests are to be made on matched batches of material at normal and sub-normal temperatures. Cooling media, consisting of liquid nitrogen, solid carbon dioxide and ice contained in the space between the two walls, enable temperatures of approximately -195° C, -75° C and 0° C respectively to be obtained in the testing space, in addition to normal room temperature. Extensive preliminary tests and temperature measurements have been made. So far static bending tests have been made on three species, ash, Douglas fir, and balsa, at normal temperature and at -75° C. Special attention is being paid to the mode of fracture at various temperatures.

ABRASION

The resistance to abrasive action of two Colonial hardwoods, East African olive and *Afrormosia angolensis*, has been determined. Both woods possess high wearing qualities and are very suitable for use as strip and wood block flooring.

A comprehensive bulletin on "Timber Flooring" has been prepared[10].

OTHER TESTS

At the request of the Accidents Branch of the Ministry of Transport and Civil Aviation an examination was made of the wing spars from a crashed aircraft. A diagnosis of the direction and sequence of fracture of the wing, which had broken off whilst the aircraft was flying, was made from examination of the fragments.

Ad hoc tests have also been carried out at the request of the manufacturers on a special type of decorators' platform. The strength of greenheart under impact has also been determined for a firm of testing specialists.

ADVISORY WORK IN TIMBER MECHANICS

Enquiries on the strength of timber and plywoods have totalled 243 during the year. The increased interest shown by architects, builders and manufacturers in the laminated timber member and the box beam have been reflected in the number of enquiries on these types of construction. Manufacturers' problems arising from sudden fractures in hockey sticks, tennis rackets, and hammer and pick-axe handles have been considered, particularly in relation to the special investigation on the strength and quality of English ash, reported elsewhere.

WOODWORKING

THEORY OF CUTTING

The work on the theory of cutting has continued using the new high-speed "whirling arm" machine described in the Report for 1956 (p. 22). During a series of commissioning runs the force-measuring equipment was improved and experimental techniques worked out; these tests also showed that the conditions of chip formation in the new machine correlated satisfactorily with those in the earlier prototype rectilinear machine.

The first series of experiments was devoted to an investigation of the effect of cutting speed on cutting forces, and the results of this work have been published[11]. They show that cutting forces decrease as linear cutting speed increases from 1000 to 3000 ft/min, thus confirming the practical observation that cutting is "sweeter" at the higher speeds.

An improved cutter-head has now been manufactured for this machine, and it is proposed to begin an investigation of the full range of cutting variables within the scope of the apparatus.

Improved force-measuring equipment is also being fitted to the low-speed rectilinear cutting apparatus; it is hoped to improve its rigidity—and hence the accuracy of cut—and also the sensitivity of the force measurement.

PLANING INVESTIGATIONS

Research in planing during the year has been confined to experiments on the commercial four-sided planing machine and further data have been obtained on the relationship of power demand to depth of cut. Planing tests on agba, at feed speed and cutting speeds of 60 ft/min and 7500 ft/min respectively and using jointed cutters, indicate that the net power demand is directly proportional to depth of cut. The effect of using unjointed cutters has also been examined and the results confirmed this direct relationship.

The effect of cutter jointing on surface finish and machine performance has been investigated. When using jointed cutters there was an average increase in power demand (expressed as a percentage of that taken by the same cutter

block when the cutters are unjointed) of 16·5 per cent and 19 per cent when planing agba and English beech respectively. The jointed cutters gave a better finish than the unjointed especially on quarter-sawn material.

A study of the rise in power demand as the width of heel is increased has indicated that the relationship is of a linear form over a range of heel width within the limits 0·2 mm to 1·0 mm and at a feed speed of 60 ft/min. A detailed report on this work is being prepared for publication.

BORING INVESTIGATIONS

A series of tests to determine the variations in torque and thrust as point angle is changed has been carried out, using high-speed twist drills. Included point angles of 100°–130° (in steps of 10°) were used. The results suggest that torque falls as the point angle is increased but the resistance to feeding (thrust) rises. The tests are continuing.

BOW SAWS

Further work has been carried out on bow saws. A complaint by the Forestry Commission that an appreciable variation occurred in the service life of saws having series of two cross-cut and one raker teeth with hardened tips has been investigated with the aid of the specially constructed sawing machine described in last year's Report (p. 22). With the object of confirming and finding reasons for their behaviour a series of sawing tests has been made on new saws and on saws that had been rejected as unsuitable for further use.

No defect in the sharpening of the new saws was readily discernible to the unaided eye but examination with a microscope revealed that the tips of the cross-cut teeth were often fractured and broken off. It was found possible to relate the extent and severity of this damage to the performance of the saw. The number of strokes required by the bow saws to cut a small area of wood varied by about 13 per cent and followed closely an index of bluntness derived from the summation of the width of the damaged tooth points actually engaged with the wood. After some use the number of strokes required to cut a fixed area of wood varied by about 29 per cent and an analysis of the results showed that, whereas the increase in the number of strokes was only 11 per cent for the saws with the least damaged teeth, it was over 21 per cent for the saws whose teeth had suffered more extensive damage. Thus, it appears that minor damage to the points of the cross-cut teeth has an appreciable effect on the initial performance of this class of saw and causes accelerated blunting, at least during the early stages of its service life.

The teeth of the saws that had been rejected by the sawyers as unsuitable for further use exhibited varying stages of bluntness. The performance of the sharpest of these saws was comparable with that of new saws but the blunter ones cut very slowly. The used blades were often twisted as a result of careless handling and these generally had a marked tendency to deviate from their line of cut. It appeared that some had been discarded for this reason, irrespective of the sharpness of their teeth. On the other hand, some had been discarded at a fairly early stage in their service life and it must be assumed that, owing to minor damage to the cross-cut teeth described above, their performance was considered sub-normal by the sawyer.

The performance of the blunter saws suggested that their use was uneconomic and that they should have been discarded earlier.

HAND SAWS

As a preliminary to a detailed investigation of factors affecting the performance of hand saws, a study has been made of the speed and direction of the motion given to such saws in normal use. By means of a regularly flashing light attached to each end of a saw in line with its teeth (Plate 3B) photographic chronocyclegrams of the motion given to it can be obtained and this has been done for a number of operators.

The information provided by these preliminary experiments has been of assistance in the development of a testing machine capable of eliminating the vagaries of hand operation.

CUTTING WITH VIBRATING TOOLS

Constant attempts are made in the woodworking industry to reduce the amount of waste, in the form of sawdust and chips, produced in most cutting operations. As it has been claimed by Russian workers[12] that this waste problem may be solved by employing a vibrating steel ribbon or wire as the cutting medium, some small-scale experiments have been carried out to verify the truth of the claim. Although the results obtained so far have no practical significance, they have established the possibility of cutting wood in this manner with the production of negligible amounts of waste.

The apparatus consists of a U-piece which carries short lengths of steel ribbon or wire under tension and is attached to a small metal plate oscillated in slideways by a motor-driven eccentric. Wood in the form of $\frac{1}{8}$ or $\frac{1}{4}$ in. slats was bolted to a slideway and was advanced to the oscillating ribbon or wire by a screw and nut mechanism.

In various experiments employing a frequency of about 50 c/s, it was found that steel ribbons having a thickness as small as 0·002 in. had little tendency to cut dense or light weight timbers when the tool was vibrated transversely in the direction of the feed motion. The cutting properties of the tool were greatly improved, however, by giving it a longitudinal oscillation and trials with movements ranging in amplitude from 0·008 to 0·020 in. showed that the cutting efficiency increased with amplitude. Square edged ribbons 0·007 in. thick, having a longitudinal vibration with an amplitude of 0·020 in., were capable of cutting $\frac{1}{4}$ in. slats of lime, Scots pine and beech, both along and across the grain, at slow rates of feed. So far the work carried out has provided only limited data on the various factors influencing this method of cutting and further experiments are planned.

DOVETAILING

The short programme of tests on dovetailed joints has been completed and the results have been submitted for publication[13].

It was found that the strength in tension of dry dovetail joints increased as the included angle of the dovetails increased up to the largest angle tested ($35\frac{1}{2}°$). Plate 4 shows the effect of a tension test on a dry dovetail joint. When the joints are glued, however, the failure of the joint occurs in a different manner and the strength is almost constant, showing only a slight tendency to be greater at the smaller dovetail angles. As the cutters for making small-angled joints are more robust it would thus appear to be advantageous to use small included angles (i.e. not greater than 15°) whenever the gluing of the joint can be relied upon.

WOODWORKING PROPERTIES

Full-scale tests have been carried out to determine the machining and nailing properties of the following softwoods supplied by the Forestry Commission:

Western hemlock, kiln-dried, from Scotland
Douglas fir, kiln-dried, from Wales, the Forest of Dean, and Scotland
Scots pine, kiln-dried, from Farnborough and Scotland
Japanese larch, air-dried, from Cumberland
Norway spruce, kiln-dried, from Scotland and Wales

Similar tests have also been made on a number of exotic hardwoods namely:

Keruing, kiln-dried, from North Borneo
Pillarwood, kiln-dried, from Kenya
Yellow seraya, kiln-dried, from North Borneo
White seraya, kiln-dried, from North Borneo

ADVISORY WORK IN WOODWORKING

The Laboratory has continued to give advice to many branches of the woodworking industry on problems concerned with the efficient sawing and machining of wood, the woodworking properties and finishing of different timbers, and on sawmilling. Enquiries dealt with during the year included a large number on the utilization of wood waste, the burning of sawdust and wood chips and the production of charcoal.

The technical enquiries amounted to 164 during the year and industrial visitors to the Section numbered 37.

COMPOSITE WOOD

PROPERTIES OF ADHESIVES

The several experiments on the long-term durability of glues continue and the issue each January of a summary[14] is proving a satisfactory way of disseminating the cumulative results. In the current issue, reference is made to the findings after the eighteen months' period of Series V and C, which are the newest tests on adhesives in current use, on development types, and on those still in the experimental stages. This work has been extended to increase the number of types of adhesive investigated and also to observe the differences within the types.

A method has been developed for testing the strength of thermoplastic wood adhesives such as polyvinyl acetate (P.V.A.) emulsions, and a report[15] has been issued. The test sample consists of three beech slips $4\frac{1}{2}$ in. $\times$ 1 in. $\times$ $\frac{1}{8}$ in. glued together with the centre component of the joint overlapped by those outside by $\frac{1}{2}$ in. This joint, which is shown in Plate 5A, is tested by laying it on edge across two rounded supports 4 in. apart, and applying a central load in a testing machine. Failing loads of the order of 300 lb were obtained with two brands of P.V.A. emulsion.

In addition, the resistance to a sustained load was also assessed using the same conditions of loading. A simple device has been developed for this test by which a single dead load is used for each set of twelve joints. Plates 5B and C show details of the device and a string of twelve samples under load. When one sample fails the device is such that the load on the remaining eleven

samples is not interrupted. With a sustained load of about 30 per cent of the ultimate (i.e. 100 Lb) the average failing time of twelve samples made with two different samples of P.V.A. emulsion was between one and two weeks. Variations in the dimensions of the joint and in its method of manufacture affect the test results, but consistent data can be obtained if reasonable limits are adhered to. The temperature and moisture content at the time of testing have considerable influence on the strength and sustained loading tests; with the two P.V.A. emulsions used in this investigation an increase in moisture content of only 3 per cent from 10 per cent was sufficient to cause a considerable reduction in the strength and the time to failure under sustained loading. For consistent results, therefore, it is essential to condition the joints before the strength test and to carry out the sustained loading test in a controlled atmosphere.

In the manufacture of blockboard cores, a rigid glue is generally employed to bond the individual slats together, and since the slats may slip slightly during this operation, the assembled core is usually planed afterwards to give a flat surface to which the veneer cross-band can be applied. It was thought that by using a thermoplastic P.V.A. glue between the slats, the need for this planing operation would be avoided, as the heat in the veneering process might soften the P.V.A., allowing the slats to slip into place, and then to re-unite as the board cooled. It was, however, found that with cores $\frac{1}{2}$ in. thick and over, the amount of heat normally used in the veneering process was insufficient to soften the glue, and levelling took place either by rupture of the glue line or by compression or fracture of the wood. Boards so made showed no defects immediately after polishing, but when subsequently exposed to wet or dry air they developed ridges or furrows over the joints between the slats[16].

In the Report for 1954 (p. 20), the investigations into the gluing of oak laminates with cold-setting resin glues were mentioned. As this work proceeded, many anomalies were found and ultimately nearly fifty variables were examined with four glues. A report is in preparation.

GLUING OF PRESERVATIVE-TREATED WOOD

Investigations into the gluing of preservative-treated wood have been extended. The results of several experiments have been analysed in respect of the four-fold combination of preservative-species-type of adhesive and the proprietary brands within a type. It has become apparent that any generalization could be misleading, so the complete results have been collated[17] in a form suitable for reference. A standard method for testing the gluing qualities of preservative-treated veneers has also been evolved[18], employing the testing procedure of B.S.1455:1956.

PROPERTIES OF PLYWOOD

Distortion

In last year's Report (p. 25) mention was made of an investigation to determine the fundamental causes of distortion in plywood of balanced construction. The work, which has involved a study of the behaviour of the veneer during the spreading and pressing processes, has now been reported upon[19]. It was found that during the closed assembly period, after the veneers were spread with glue and before pressing, the solvent water in the adhesive was gradually absorbed by the wood, which expanded across the grain. In the subsequent hot pressing, the crossed veneers were bonded together whilst in the expanded state but, at the

same time, moisture was driven off. As the veneers could not shrink, stresses were developed, but in a manner complicated by the plasticizing effects of the heat and moisture and the characteristic of the wood to assume a permanent set under sustained loads. These stresses increased with the pressing temperature and with the moisture content of the wood and were more severe at the edge of a five-foot square veneer than at the centre. On opening the hot press and during the unloading, the faces of the plywood dried and additional stresses were developed in the surface veneers. These stresses also increased with the pressing temperature and the moisture content but were greater at the centre of the board than at the edge. During the subsequent conditioning of the plywood to the moisture content of the veneers before spreading, the stress level was generally reduced but the variation over a five-foot square veneer increased.

This analysis showed that the main cause of distortion in plywood of balanced construction was variation in the stress developed in the veneers during the pressing process, but the effect of this variation would be minimized if the veneers could be spread and immediately pressed at a temperature of the order of 75° C (167° F). At this temperature, the moisture content of the plywood on leaving the press is similar to that of the veneers before spreading, the stresses developed in the veneers are low in intensity and more uniform in distribution, and the effects of plasticizing and permanent set are negligible.

Surface Protection

When plywood is exposed to the weather, it will not delaminate if the adhesive is of the correct type and has been properly used, but the surface veneer will suffer considerably. In colour, it will tone to a uniform grey, and the wood will become rough and friable. Paints afford some protection, but require periodic renewal and are insufficiently hard to resist abrasive action. The possibility of creating a tough reinforced plastics layer as an integral part of the surface of plywood was investigated jointly by this Laboratory and the Chemical Research Laboratory during the last war but the results found no immediate application. In recent years, however, there has been a revival of industrial interest, and the Laboratory is collaborating with suppliers in assessing the suitability of various treated papers. Methods have been devised for testing the bond between the plastics and the wood, for assessing the technical appearance of the film, and for finding their durability under various natural exposures.

Defects of Plywood

The investigation to find the conditions which give rise to defects on veneered surfaces continues[20]. The first stage deals with the thickness and quality of peeling of beech veneer used on the face of the plywood base and also with the moisture content of this base.

One of the most common defects known to occur on veneered panels is corrugation of the surface arising from lathe checks in the face ply of the groundwork. Corrugations develop in the decorative veneer and ridges or depressions occur immediately above a lathe check in the face ply depending on whether wetting or drying of the panel has taken place. The manner of the development can be appreciated by visualizing a cross-section through the surface layers of a veneered panel with the ply immediately beneath the decorative veneer in cross-section. This ply can then be regarded as a number of small segments, glued to the decorative veneer on their top faces and to the ground work on their lower faces, and of such a shape that the spaces between them are of lenticular

section. Drying of the panel then results in these sections becoming more convex since shrinkage of the segments is prevented near both their faces but is permitted to an increasing degree towards their mid-depth.

As a result of this change in shape, the surface veneer is pulled inwards, and a depression occurs on the veneered surface. The upper photograph of Plate 6 shows what has taken place on drying, the lower photograph how the process reverses itself if the panel is wetted and how depressions have changed to ridges.

The present tests have already confirmed that corrugations occur whether the face of the under-veneer containing lathe checks is laid outwards or inwards provided, of course, that a change in moisture content takes place. It has also been shown that ridges on the surface of a veneer laid on loosely peeled under-veneer 3 mm thick can be changed to furrows by reducing the moisture content less than 3 per cent. The effects are considerably reduced by using a thinner under-veneer. Similar effects have been observed on lacquered plywood where the lacquer film appears to behave rather like a thin wood veneer.

THE DRYING OF VENEERS

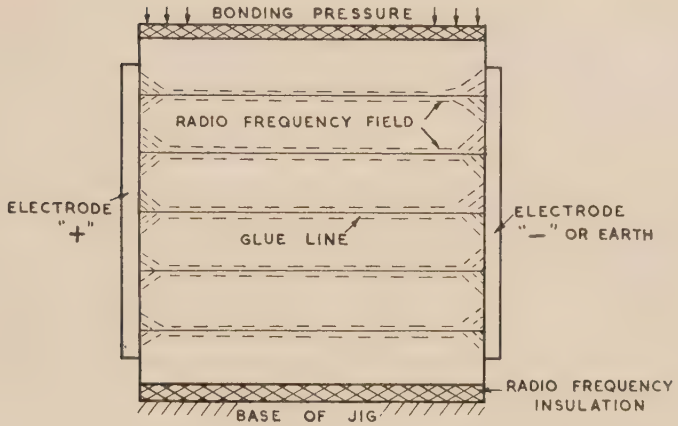
In recent years numerous papers have been published on the drying of veneers in mechanical dryers and a survey has been made of the available information[21]. It seems that in veneer drying at temperatures above the boiling point of water the laws for the diffusion of water vapour through wood no longer apply and the governing factor is the rate at which the heat is supplied to the veneer. This hypothesis is based on the performance of small accurately cut samples, matched for grain and dried in closely controlled experimental dryers. There is, however, some evidence that the size of the sample is important and it is probable that this interpretation will have to be modified when applied to commercial-size veneers. The survey has also shown the absence of any information on the causes of the wide variation in the drying rate known to occur in veneers. Tests have shown that it is necessary to dry commercial-size veneers to an average moisture content of 6 per cent to ensure that the upper limit of the variation does not exceed 20 per cent moisture content. This survey has served to show the gaps and anomalies in the available data and will provide a basis for the planning of future investigations.

TRIALS OF TIMBER FOR PLYWOOD MANUFACTURE

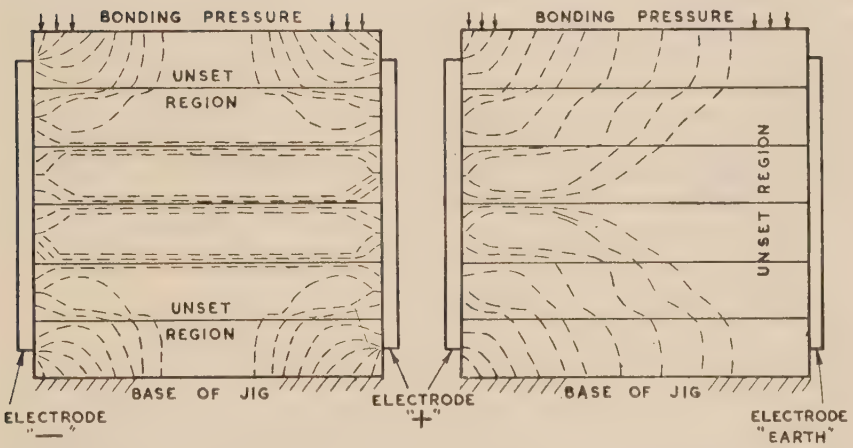
Plywood manufacturing trials have been completed on nkobakoba, bosquiea and white star apple from Uganda, East African olive from Sudan and keruing from North Borneo.

RADIO FREQUENCY HEATING

In last year's Report (p. 29) mention was made of the application of radio-frequency glue-line heating to the manufacture of laminated beams and a method was described for determining the variation in heating rate over a glue layer. This work has now been completed[22]. Across an 8-in wide laminated beam the variation in heating rate was found to be negligible if adequate radio frequency insulation was incorporated in the pressure platens of the jig to contain the field between the electrodes. Fig. 3 shows diagrammatically the effect of this insulation. Two cases are considered, firstly when the generator output is balanced about earth potential and, secondly, when one terminal is at earth potential.



With radio frequency insulation



(i) *Generator output balanced about earth potential*

(ii) *Generator output at earth and above earth potential*

Without radio frequency insulation

Fig. 3. The radio frequency field in a laminated beam under glue-line heating

Along the length of a 5-ft beam, fed at one end with radio frequency power, there was a variation in heating rate ascribed to the formation of standing waves in the electrodes. This variation can, however, be minimized by the choice of frequency and the location of the feed points.

The species of the laminae comprising the beam affect the setting time for the adhesive. Slower cures were obtained with high density woods such as oak than with the lighter species such as obeche. The amount of the glue spread and the moisture content of the laminae also affect the setting time but to a lesser extent.

One of the disadvantages of radio frequency heating is the complexity of the jigs necessary for its application. Not only must a jig locate the components of the joint and apply the bonding pressure but it must also contain the electrodes for supplying the power. In an effort to overcome this disadvantage in the gluing of a batten to a sheet of plywood, a joint common in furniture, the stray field platen has been used. It consists, essentially, of a number of parallel electrodes connected in turn to the generator terminals and incorporated in the upper of the two platens that form the basis of the jig. In use the battens are usually located on the lower platen, the plywood laid in place, and the assembly raised to the fixed top platen containing the electrodes. With this arrangement it is possible to alter the batten positions and the size and shape of the plywood without disturbing the electrodes. The penetration of the stray field between the electrodes into the glued assembly is affected by the design of the platen itself as well as by the properties of the joint being heated, and an investigation to study these factors has been completed[23]. An experimental stray field platen was first constructed to investigate the effect of the electrode spacing and width. It is considered that the most satisfactory electrode arrangement consists of 1-in. wide electrodes with a 1-in. air gap between them. A platen was constructed with this arrangement and the effect of variables in the joint itself determined. For any one size of joint the area of set glue at the end of the heating period increased with the amount of glue spread. A maximum was reached, however, at about $4\frac{1}{2}$ lb/100 sq. ft of single glue line beyond which the effect of glue spread became negligible. The area of set glue at the end of the heating period also depends on the moisture content and density of the wood. More set glue was obtained at the high moisture contents than at the low, and at the low densities than at the high.

ADVISORY WORK IN COMPOSITE WOOD

The enquiries during 1957 totalled 417.

WOOD PRESERVATION

TREATMENT BY IMMERSION METHODS

In recent years preservative treatment has been used to an increasing extent in the field of building construction as a precautionary measure against possible attack by insects or decay. Much of the timber used in buildings is redwood which now generally contains a large amount of sapwood. This is very liable to fungal decay if the timber becomes damp and is also subject to attack by the common furniture beetle.

The main methods of treatment suggested in the *B.S. Code of Practice* 112: 1952 for the preservation of timber in buildings are pressure impregnation and immersion treatments.

The sapwood of redwood is permeable and is readily impregnated by pressure methods but not much is known about the degree to which it can be treated by immersion. Some work has therefore been carried out to determine the penetration and loading of preservative that can be obtained by this form of treatment.

The preservatives of particular interest for the preservation of building timbers by this method are those of the organic solvent type. There are many of these and it was found that they do not all possess quite the same

penetrating power. To avoid repeating the work with several different formulations white spirit was used to represent the organic solvent type. It is commonly employed as a solvent in this type of preservative and preliminary comparative tests established that it was equal to or somewhat better in penetrating power than the main varieties of these preservatives.

It was found that this solvent will penetrate the sapwood of redwood to an average depth of about $\frac{1}{4}$ in. after dipping for 10 seconds and about double this after immersion for 1 hour. If the treatment is continued for several hours complete penetration of the sapwood contained in common structural sizes can be obtained. The volume of solvent absorbed during an immersion treatment, however, is small, and its concentration in the treated zone of the wood is low compared with that obtained by impregnation methods. This could be an advantage because it enables the toxic constituents of the preservative to be carried in to a given depth with a low volumetric retention and thus a comparatively low consumption of solvent. On the other hand it means that care must be taken to see that the amount of toxic constituents in the preservative is high enough to ensure that their final concentration in the treated zone of the wood is sufficiently above the toxic limit.

It has been established that the reason for this low concentration is that penetration occurs mainly along the medullary rays which, it is estimated, represent only about 5 to 7 per cent of the void volume of the wood.

Experiments with both the solvent and with typical solvent preservatives also showed that penetration may continue to occur after the wood has been removed from the preservative. It has not been determined for precisely how long this goes on, but observations over a period of six months showed that it had finished at some time less than a week. The penetrations mentioned above were measured after movement of the solvent had stopped.

A report on this work has been prepared for publication.

DISTRIBUTION OF PRESERVATIVES IN WOOD

Previous work, described in last year's Report (p. 30), has shown that when a permeable timber is completely impregnated with dilute solutions of creosote in a volatile solvent the creosote migrates towards the surface as the solvent evaporates and steep concentration gradients are set up in both the longitudinal and lateral directions. This investigation was carried out to establish the kind of distribution which would be obtained in the large-size samples normally used in field tests. Further work has shown that similar concentration gradients occur also in the small blocks used in the standard laboratory tests for determining toxic limits against fungi and insects (Plate 7). The normal procedure in these tests is to introduce the preservative material in solution in a volatile solvent and the results suggest that there is some degree of uncertainty in the toxic limits and threshold values determined by these methods.

An account of this work has recently been published[24].

IMPREGNATION TESTS

Standard impregnation tests have been carried out on kapur, keruing, muchenche, pillarwood, light red, white and yellow seraya and on the following home-grown softwoods; Corsican pine, Douglas fir, grand fir, western hemlock and larch. The resistance to impregnation of about 150 different species of wood has now been assessed by these tests. During the year the results of this work have been summarized and a report has been prepared.

PERMEABILITY OF TIMBER

Work has continued on the permeability of the common softwoods. Measurements of radial and tangential permeability involve sealing the end-grain surfaces and a new technique has had to be developed for this purpose. The wax sealing method which has been used satisfactorily on lateral surfaces proved to be unreliable on end grain. It was found that even a finely sawn end-grain surface cannot be sealed satisfactorily because the fibres are torn and partly burred over. Consequently a sealing medium does not reach the open end of every tracheid and some of them are left unsealed. Where these are adjacent, flow can take place from one to the other between the wood surface and the seal. No practicable method of cutting could be found which would produce an end grain surface capable of being sealed reliably but eventually a suitable surface was obtained by fine sanding using an open-grade resin paper.

An interesting feature of the results which have been obtained so far is that the ratio of longitudinal to lateral permeability is generally much greater than has previously been supposed from observations on the penetration of preservatives.

TREATMENT OF WESTERN RED CEDAR SHINGLES

It is now known that in this country western red cedar roofing shingles may begin to deteriorate slowly through fungal decay after a number of years and it is believed that some form of preservative treatment would be beneficial. Some tests have been started to assess the value of a spray treatment for the prevention of further decay in roofs which have already begun to deteriorate. They are being carried out at the Laboratory on a 23-year-old roof, areas of which have been treated with creosote, a water-borne and two solvent-type preservatives respectively. Other matched areas have been left as controls. Complementary tests have also been started to determine the effectiveness of a surface treatment applied at the time the shingles are laid and repeated if necessary. For these tests a light creosote and two colourless solvent-type preservatives are being used.

ADVISORY WORK IN WOOD PRESERVATION

The number of enquiries dealt with by letter was 395.

MYCOLOGY

CULTURE COLLECTION

The collection of cultures of wood-rotting fungi has been maintained in good condition and detailed descriptions of 16 more fungi in culture were prepared. Seventy-four cultures were supplied to other research laboratories and to firms. Fructifications of wood-rotting fungi received from the University College of the West Indies in Jamaica were identified and placed in the herbarium.

SOFT ROT INVESTIGATIONS

Although it is known that cellulose-destroying micro-fungi can bring about soft rot in coniferous woods in the field, it has not hitherto been possible to bring about similarly rapid decay under laboratory conditions. For the first time good growth of *Chaetomium globosum* and marked decay in softwoods have been

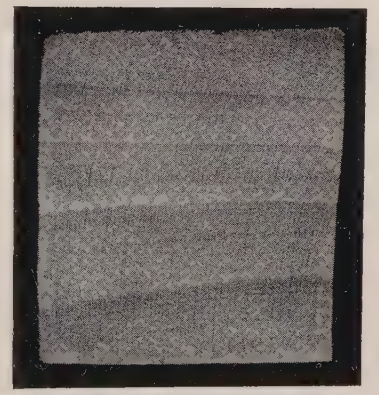
Basketry willow stacked for kiln drying

PLATE 1

(A) Cross-section of red heart beech specimen with internal splitting after R.F. heating ; corresponding photomicrograph of the radial section showing tyloses in the vessels (V)

A

(B) Cross-section of normal beech specimen free from splitting after R.F. heating; corresponding photomicrograph of the radial section without tyloses



B

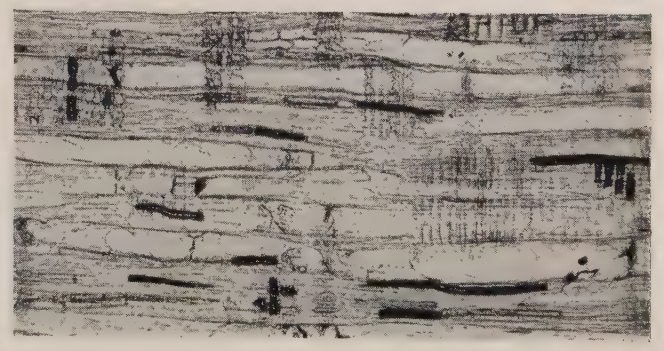
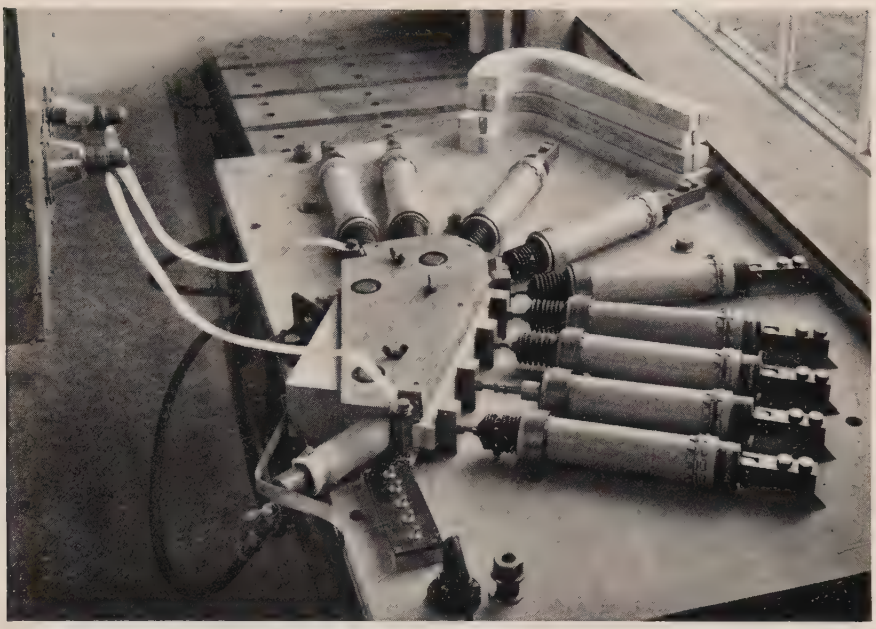
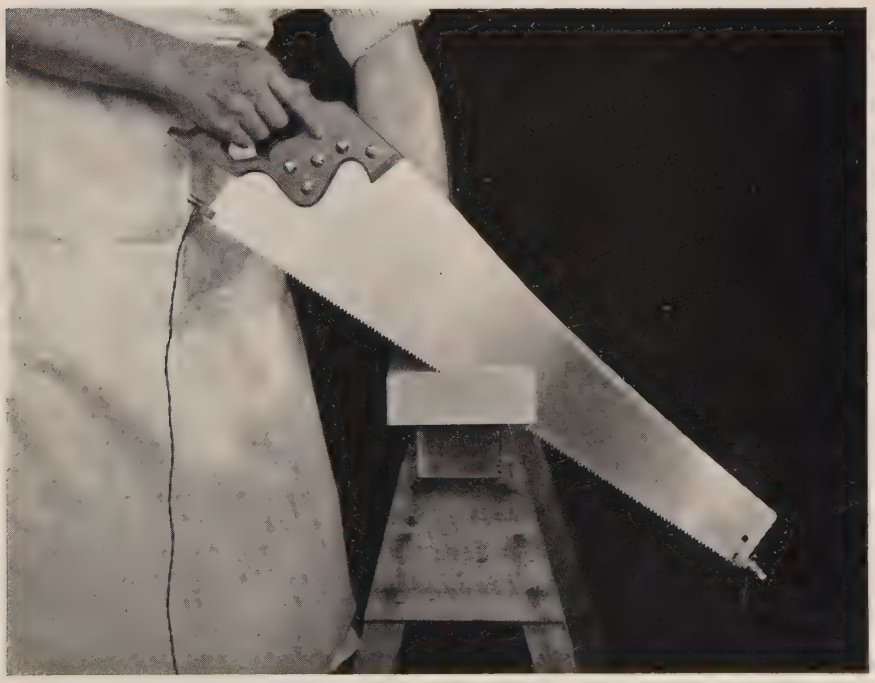


PLATE 2

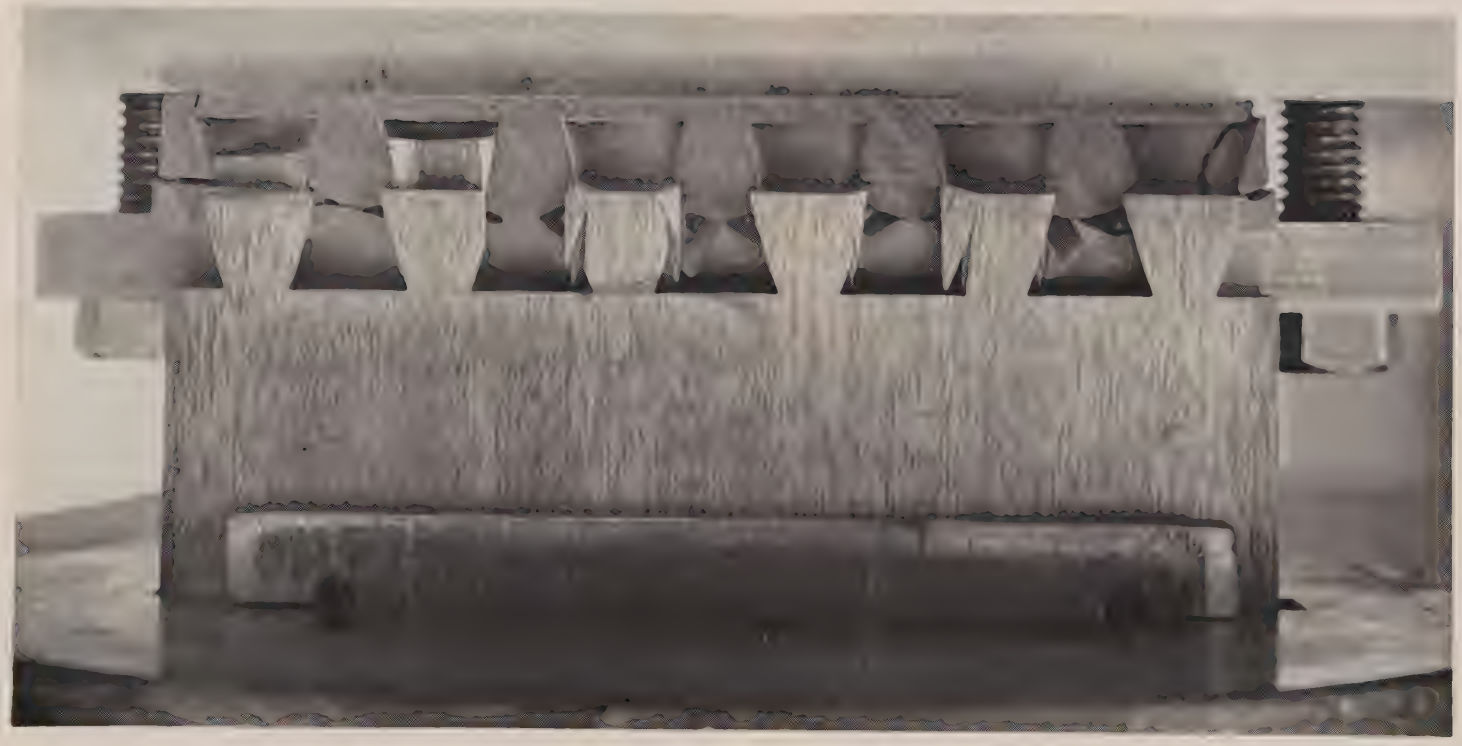


(A) Pressure and gluing jig incorporating R.F. heating used in the manufacture of an Indian type two-piece hockey head



(B) Lights attached to a saw for the study of hand-sawing action

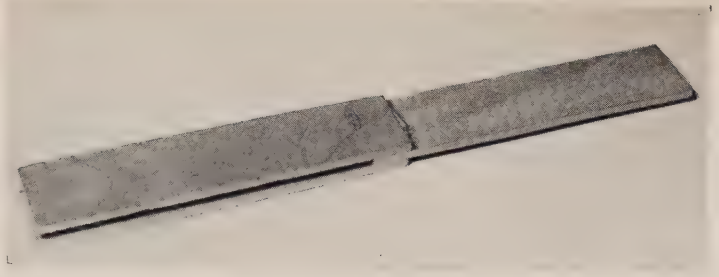
PLATE 3



Tension test on an unglued dovetail joint with an included angle of $35\frac{1}{2}^\circ$

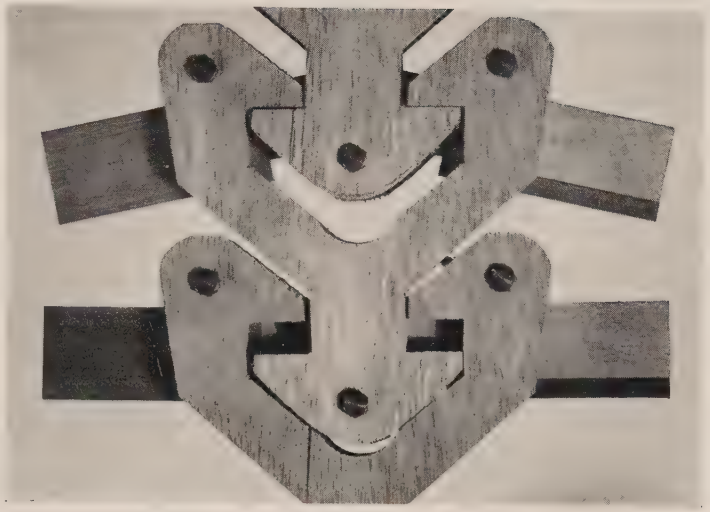
PLATE 4

(A) The double lap sample used in the strength test



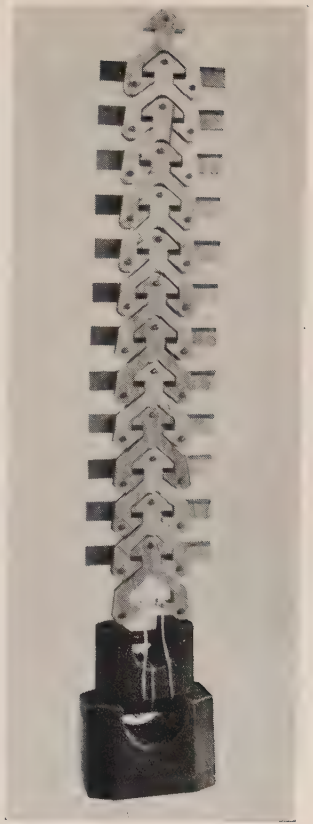
A

(B) The method used to determine the resistance of thermoplastic glues to sustained loading



C

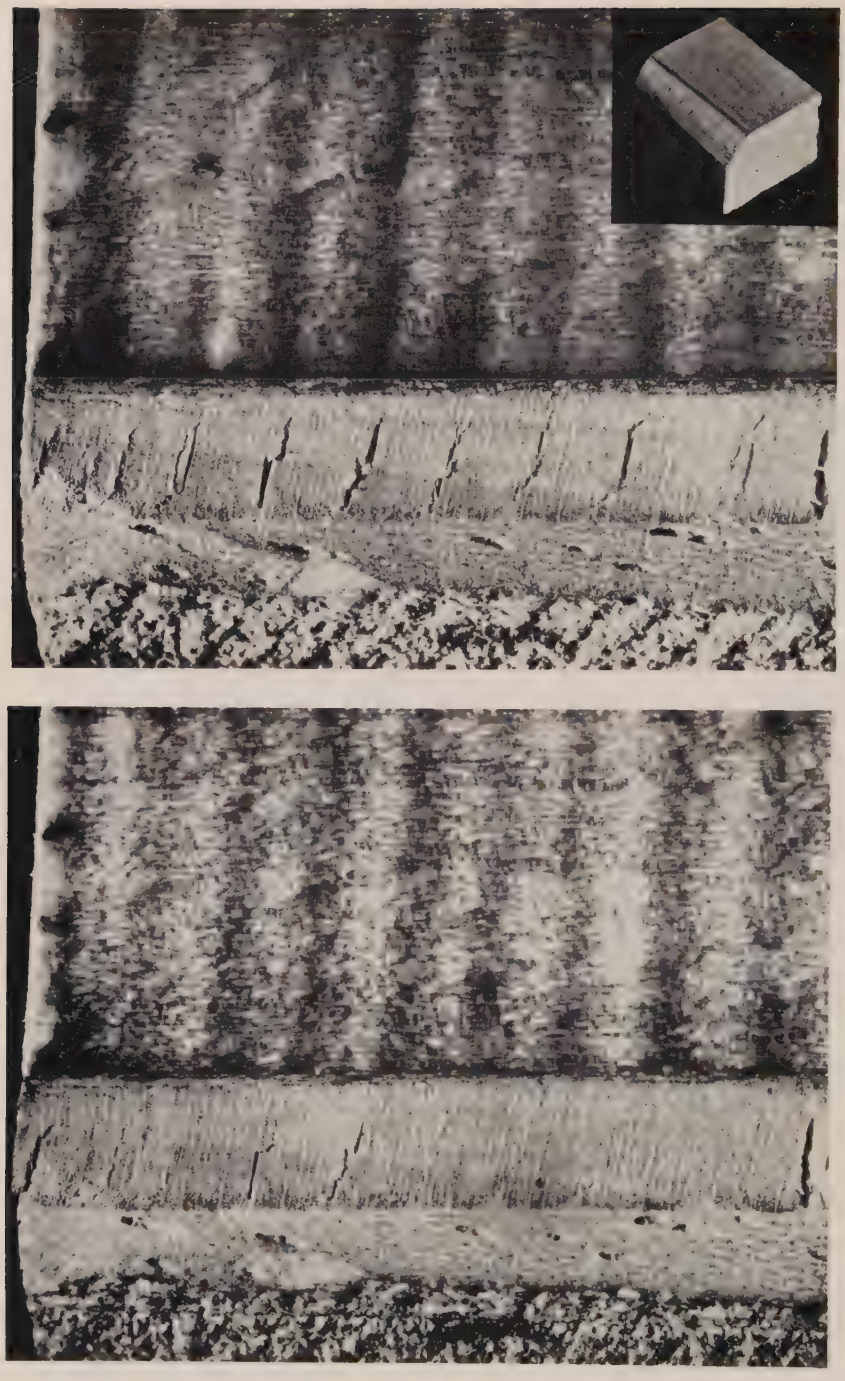
(C) Details of the sustained loading device. Failure of one sample does not interrupt the load on the remainder of the samples.



B

Testing thermoplastic wood adhesives

PLATE 5

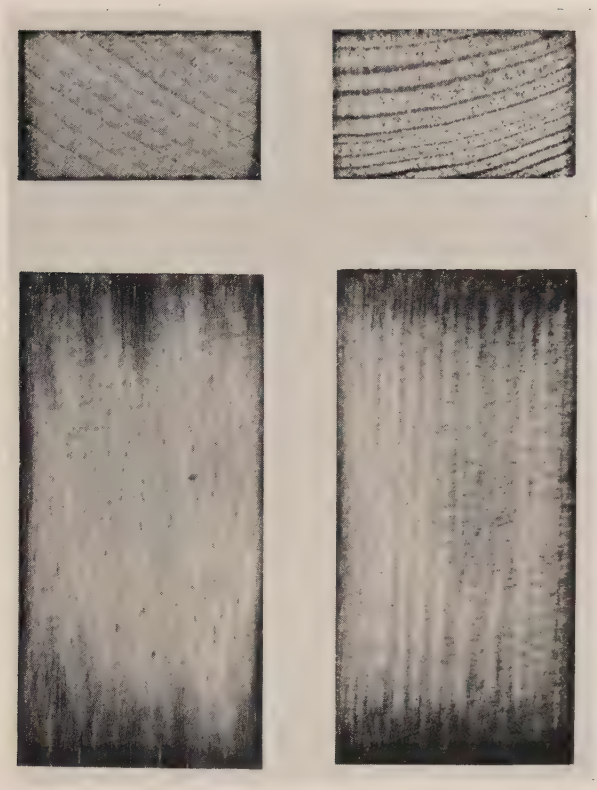


Inset—Block approx. $\frac{4}{5}$ natural size.

Above—In the dry state the lathe checks in the veneer underlying the decorative surface are open, causing a furrow above each.

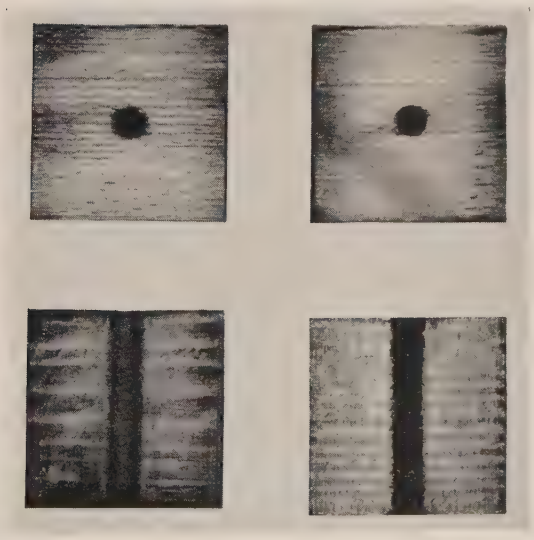
Below—In a damp condition the lathe checks are almost closed. A ridge occurs above each lathe check and corresponds in position to a furrow in the upper photograph. Magnification × 4.

Corrugated surface and oblique section of surface plies of veneered plywood block.



Beech Scots Pine

European type test blocks

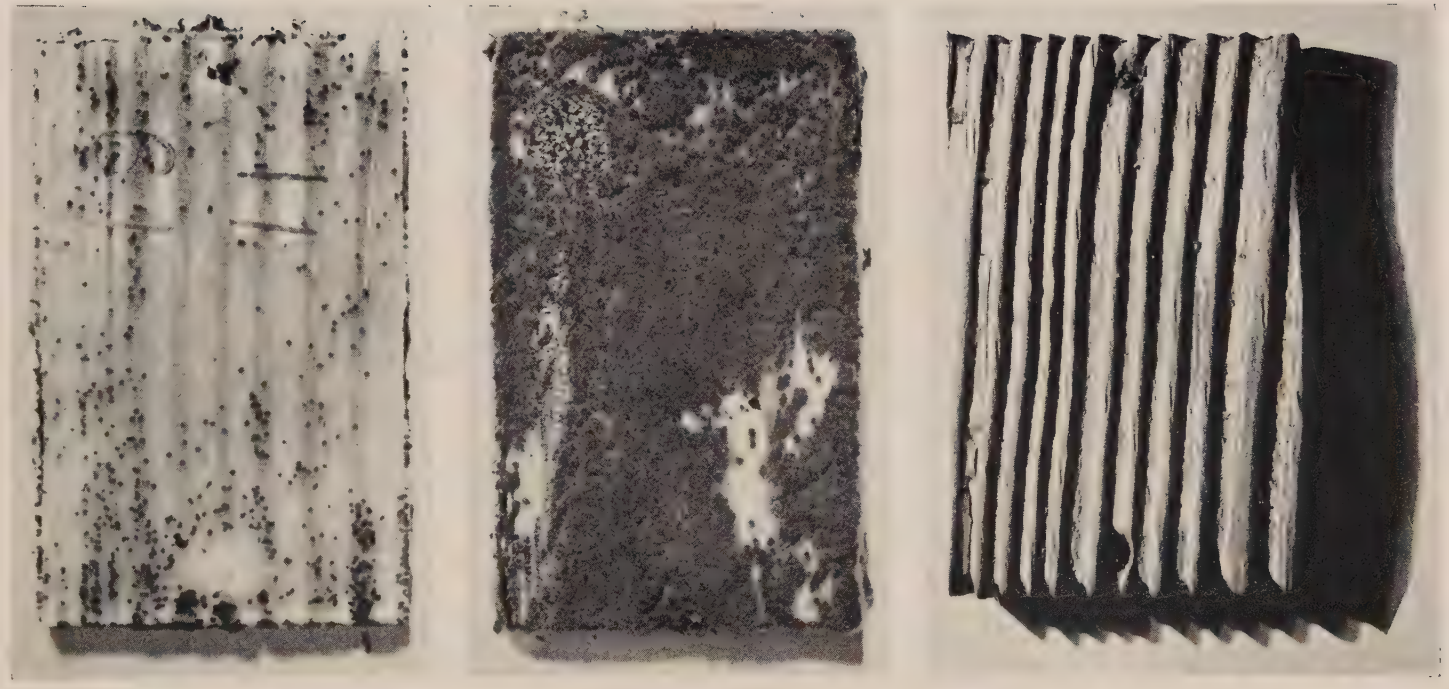


Beech Scots Pine

American type test blocks

Redistribution of creosote in test blocks after evaporation of the solvent.

PLATE 7



(*a*) Untreated block after exposure to the fungus

(*b*) Chlorinated block after exposure to the fungus

(*c*) Chlorinated block after removal of the fungus and drying

Growth of *Chaetomium globosum* causing soft rot on Scots pine

PLATE 8

obtained in the laboratory by treating the samples of Scots pine sapwood with chlorine water before they were exposed to the fungus. Samples which had lost about 5 per cent of their dry weight through the action of the chlorine, which presumably brought about some change in the lignin of the wood, were washed to remove all traces of the chemical and then exposed to *C. globosum*. The fungus grew vigorously over the chlorinated blocks and in six weeks brought about a further dry-weight loss of 16 per cent. Growth was sparse over the untreated blocks, which suffered only a negligible weight loss (Plate 8). This effect of chlorine may be of considerable significance in accelerating the progress of soft rot in the timbers of water-cooling towers and further work is planned in order to find out what degree of chlorination is necessary to encourage the growth of *Chaetomium*.

The search for other micro-fungi that may cause soft rot of wood in contact with the soil continues and small pieces of sterilized beech have been exposed to soil obtained from various situations. Treated test pieces from the "graveyard" exposure sites have been examined in order to determine to what extent their failure has been due to soft rot. It has been established that the optimum temperature for the growth of *Chaetomium globosum* in beech wood is about 29°C.

LABORATORY TESTS OF WOOD PRESERVATIVES

Requests for standard laboratory tests on wood preservatives continue to be received from manufacturers: full standard tests on seven products and tests on two surface-applied treatments have been carried out on behalf of firms. The toxicity to *Chaetomium globosum* of a number of products has also been determined and these tests were carried out in duplicate with samples that had been exposed to a leaching treatment after impregnation.

A series of tests has been started to determine the residual toxicity of surface treatments with various preservatives after long periods of exposure to the air under conditions simulating those in a roof. It has already been shown that treatment of air-dry Scots pine sapwood blocks by immersion for ten minutes in 5 per cent pentachlorophenol solution does not give permanent protection against attack by *Coniophora cerebella* whereas a comparable treatment with an aqueous 4 per cent sodium pentachlorophenate solution effectively protected the samples at least for the period of test.

The results of a series of tests in which feeder blocks over soil or vermiculite were used as a medium for growth of the test fungi have been reported to the British Standards Institution. It was noted that individual fungi differ appreciably in their reactions to different media, but on the whole soil is superior to vermiculite. It was found that, quite consistently, more decay of test blocks occurred over vermiculite when the test bottles were stored horizontally than when they were stored upright.

Some laboratory work has also been carried out on behalf of the B.S.I. Committee and the rate of loss of creosote from impregnated test pieces undergoing weathering treatments has been followed.

Further tests have been carried out to determine more accurately the range of concentrations of sodium fluoride which stimulate decay by *Coniophora cerebella*. As reported in the Report for 1956 (p. 34), the maximum rate of decay occurred in wood treated with 0·02 per cent solution, the weight loss then being about twice that of the untreated controls. Marked stimulation has also been found at 0·03 per cent and 0·04 per cent, but at 0·05 per cent

there was slight inhibition in one test but very slight stimulation in a second test. At a concentration of 0·02 per cent decay by *Poria vaporaria* was also stimulated, the control blocks having an average weight loss of 21 per cent and the treated blocks of 33 per cent.

Treatment with a concentration of 0·0025 per cent copper sulphate was found to accelerate decay by *Poria vaporaria* but low concentrations of zinc chloride were not found to increase the rate of decay by *Coniophora cerebella*.

Tests are in progress to discover if low concentrations of arsenic pentoxide stimulate decay by *Lenzites trabea*, a fungus tolerant of arsenic.

LABORATORY TESTS OF NATURAL DURABILITY OF TIMBERS

Standard laboratory tests have been carried out to determine the resistance to decay of white and light red seraya and of four timbers from Chile: lenga, nirre, tineo and ulmo. At the request of the Colonial Development Corporation, an investigation has been undertaken to determine the extent and decay resistance of the sapwood in greenheart poles. It is difficult visually to distinguish between the sapwood and heartwood in this timber and a mycological test may be the most reliable method for distinguishing between the two zones.

In the Report for 1956 (p. 35) mention was made of the premature failure of some western red cedar seed boxes which had been attacked by *Merulius sclerotiorum* (= *M. pinastri*). It has been confirmed that this fungus can cause up to 10 per cent loss in dry weight in western red cedar samples that have been exposed to a leaching treatment which had removed about 3·8 per cent of their original dry weight, but under laboratory conditions it causes no significant attack in unleached cedar samples.

M. sclerotiorum made good growth on malt agar medium containing an aqueous extract from western red cedar wood and formed yellow strands similar to those observed on the decayed boxes. The premature decay of the boxes would thus appear to be due to chance infection by a rather rare fungus that has some resistance to the natural preservatives in western red cedar wood. Also the decay resistance of the timber had been lowered by leaching out of some of the extractives. No doubt the high fertility and porosity of the soil used in the boxes contributed to the vigour of the fungus growth.

DRY ROT INVESTIGATIONS

The relative efficacy of sodium pentachlorophenate and sodium orthophenylphenate solutions for the sterilization of brickwork infected with *Merulius lacrymans* has been examined in laboratory tests and found to be approximately the same. There are indications that neither chemical will rapidly lose its effectiveness if applied initially in 5 per cent concentration.

DECAY OF TIMBER IN BOATS

During a visit to a Thames boat yard confirmation was obtained that soft rot of the outer surface of African mahogany planking below the water line occurs on a sufficient number of river craft to cause concern. It was noted that the soft rot attack, which was not confined to any particular plank or area of the hull, develops where the under-water planking is bitumen-treated but is absent where copper-containing marine anti-fouling paints are employed.

Tests of the protection given to timber in the bilges by treatment of the bilge water with pentachlorophenol are being carried out in co-operation

with a marine surveyor. Arrangements have been made for a series of test pieces of beech wood to be fixed in the bilges of several boats in which the bilge water has been treated. The decay resistance of these test pieces will be examined in the laboratory after various periods of exposure in the bilges.

SAP-STAIN AND MOULD INVESTIGATIONS

Pilot-scale tests of the effectiveness of two new organic fungicides as preventatives of sap-stain in softwoods have been carried out on pine sapwood.

Owing to the difficulty of obtaining suitable unstained tropical hardwoods for use in sap-stain tests, investigations have been carried out to discover which of the common home-grown hardwoods would be most suitable. Hazel wood and horse chestnut have been found to stain readily with *Lasiodiplodia theobromae* and it is therefore proposed to use the latter timber for the testing of sap-stain preventatives.

The rate of growth of *Lasiodiplodia theobromae* across the grain of ramin has been determined under laboratory conditions and was found to be slower than along the grain.

An experiment to determine the temperatures required to kill *Diplodia natalensis* on agar has been carried out. It was found to be resistant to heat. Exposure in a saturated atmosphere to a temperature of not less than 65° C for several hours would be necessary to sterilize wood infected with this fungus.

Three species of fungi isolated from moist sawdust incubated at 48° C have been tentatively identified as *Aspergillus fumigatus*, *Monotospora lanuginosa* and *Thermascus aurantiacus*. The last two organisms are true thermophilic species and will not grow at room temperatures. *M. lanuginosa* has an optimum temperature of about 48° C and makes some growth at 61° C.

The resistance to mould growth of an insulating material made of expanded polystyrene has been examined on behalf of its manufacturer.

PHYSIOLOGY OF WOOD FUNGI

It has been shown that *Coniophora cerebella* can grow along the grain of moist Scots pine sapwood at 22° C at a rate of 0·8 cm per day. Under similar conditions growth in heartwood is very much slower and does not appear to exceed a rate of 1·0 cm per week.

PREVENTION OF DETERIORATION IN LOGS

The test referred to in the Report for 1956 (p. 36) has been completed. Bolts of beech in which the ends and bark scrapes had been coated with gasworks tar were not found to be adequately protected against infection by wood-rotting fungi. The bolts that had been treated with the tar were in somewhat better condition than the untreated logs after exposure for 11 months. Their condition, however, was not as good as those which in a previous experiment had their ends coated with a thick bituminous coating applied after a fungicidal wash.

ADVISORY WORK IN MYCOLOGY

The number of advisory enquiries dealt with was 981, being approximately the same as in the previous year. Thirteen inspections of buildings infected with dry rot were carried out on a fee basis. Many enquiries concerning the cause and prevention of staining in timber were received.

ENTOMOLOGY

COMMON FURNITURE BEETLE (*Anobium punctatum*)

Survey

Over a period of years, information has been collected at the Laboratory upon the occurrence and general distribution of this common household pest. Housing managers and others responsible for the maintenance of property have long been concerned with infestation by this insect but few accurate data are available on the incidence of attack in houses of different ages. An opportunity arose during the year of starting an enquiry into the occurrence of this type of insect damage in council property with the co-operation of the housing department of a rural district council. Houses erected before and since the last war have been visited and structural woodwork, joinery and furniture examined. It has been noted that although infestation by the common woodworm is not always present, it is much more frequent in older houses, where infestation may be widespread. The common belief is that infestation is usually associated with woodwork that has been in service for many years but examination of post-war houses, 7–9 years old, has revealed slight localized attacks. Introduction of attacked furniture into new houses appears to be an important factor in determining the period that may elapse before infestation of the structure commences.

Behaviour and Life-history Studies

Records of emergence from doors of New Zealand white pine, *Podocarpus dacrydioides*, stored in an insectary out of doors since 1951 have been continued. In the summer of 1957, emergence began and ended approximately two weeks earlier than in 1956, doubtless owing to the warm spring, which probably also accounted for the increased emergence, particularly of females, as compared with the previous year. The numbers of beetles collected and removed from the insectary during the past seven summers have been as follows:

Year	*Males*	*Females*
1951	1848	1249
1952	1627	1054
1953	1305	831
1954	1329	973
1955	1451	953
1956	1122	495
1957	1255	672

These figures are of interest in relation to the sex ratio of the insect and confirm previous indications that the females may remain within, or return to, their tunnels during unfavourable temperature conditions.

Studies of rate of larval development have been continued. Examination of small blocks of Corsican pine sapwood into which larvae, varying in weight from 6 to 18 mg, were transferred in 1954 and since kept at 22° C and 86 per cent relative humidity has shown that larvae up to 12 mg gained in weight over the 3-year period, whereas larvae initially above this figure lost weight. It thus seems that under such equable conditions, known to be unsuitable for pupation, a stage in growth is reached at which further increase is limited.

Effect of Fungal Decay

Examination has now been completed of most of the samples of oak sapwood and heartwood decayed to varying losses in weight by the white rot fungus, *Phellinus cryptarum*, and of sound control samples exposed for egg-laying in 1955. The results are, however, unsatisfactory since in the case of sapwood, for some unknown reason, few larvae survived either in the controls or in the decayed material. In decayed sapwood blocks in which a few live larvae were still present the results obtained confirm previous indications that larval growth is more rapid in decayed than in sound wood. No larvae survived in any of the heartwood material decayed to losses in weight between 8 and 41 per cent, nor in sound controls. It is interesting to recall, however, that instances of infestation by this insect have been noted in decayed oak heartwood in buildings.

A further experiment has been set up to study the effect of decay by soft rot on the suitability of beech for attack and an investigation of the effect of the presence of blue stain in Scots pine sapwood in relation to infestation by this insect has been started.

Tropical Hardwoods

Samples cut from arbitrarily fixed zones of obeche from the periphery over the outer 12 in. of radius, exposed for egg-laying in 1954 and kept at 22° C and 86 per cent relative humidity and also out of doors have now been examined. Eggs had been laid on the samples and although hatching took place, no larvae survived.

Plywood

Further samples of the birch plywood made up in 1953 with various types of glue and exposed for egg-laying in 1955 have been examined. In contrast to previous indications (see the Report for 1955, p. 36) it has been found that blood glue is at least as suitable as blood/casein glue for larval growth. Furthermore, it has been noted that plywood made up with either glue is more suitable than solid wood controls, as judged by the average larval weight obtained in the three types of material. The unsuitability of plywood bonded with urea/formaldehyde glue has again been confirmed, no larvae surviving from eggs laid on such samples. In the course of examination of this plywood exposed in previous years for egg-laying, it had appeared that of steamed and unsteamed birch used in its manufacture, the former was the more suitable for infestation by the common furniture beetle (see Report for 1955, p. 36). As the material then used had been obtained from different logs it could not be determined at the time whether this variation in susceptibility to attack could in fact be attributed to the steaming. A further experiment has been started using discs from a fresh birch log, some having been submitted to a range of steaming treatments and alternate ones remaining unsteamed.

A new experiment has been started with obeche to determine its suitability for attack when made up as plywood with blood/casein glue in relation to the apparent unsuitability of solid wood.

HOUSE LONGHORN BEETLE (*Hylotrupes bajulus*)

Occurrences

Five further instances of active attack in buildings in parts of Surrey, in which the insect is known to be prevalent, have come to notice during the year; in one instance the insect was breeding in garden fence posts. Isolated

infestations have been reported from Southampton, Wembley and Co. Antrim. Active attack in the floor boards of a farm-house in Jersey is believed to be the first recorded instance of damage by this insect in the Channel Islands; two further cases of infestation in Jersey houses have since been found. Three instances of long-standing extinct attack were noted in old houses in the outer London area. Live larvae were found in an Italian tomato crate and in two Spanish orange boxes, of which one, in Surrey, had been in store in this country for at least five years.

Moisture Relationships

Investigations have been continued into the effect of varying moisture content of wood on its suitability for larval development. Newly-hatched (egg) larvae inserted into the transverse section of discs of Scots pine sapwood conditioned to a moisture content of 10 per cent and maintained at 25° C did not develop. Some larvae similarly introduced into wood of approximately 27 per cent moisture content and kept at the same temperature grew in 43 weeks to more than 400 mg in weight. Within the same sample of wood, however, considerable variation in larval weights was noted and may be attributed to differences in the nutritional value of parts of the wood in which individual larvae were feeding.

In view of the inhibiting effect of water leaching on the nutritional value of wood for the larvae of this insect (see last year's Report, p. 40) an experiment has been set up to investigate the effect of steaming on the suitability of timber for attack. Sapwood of freshly felled Scots pine cut to suitable sizes was steamed at atmospheric pressure for 8–16 hours. Egg larvae were then introduced into the wood, which was kept at 25° C and 75 per cent relative humidity. Examined after one year, a marked difference in the rate of larval growth was noted. In samples steamed for eight hours, larvae weighing between 0·5 and 1·0 mg were obtained, whereas in unsteamed control samples the larvae weighed from 31 to 98 mg. Full results are not yet available and the work is continuing.

AMBROSIA (PINHOLE BORER) BEETLES

Oak Pinhole Borer, Platypus cylindrus

Investigations on this insect have been continued by an officer of the West African Timber Borer Research Unit stationed at the Laboratory.

Further observations have been made on the progress of attack in logs at the Laboratory and in logs and stumps on field sites. Emergence of a new generation of beetles from oak logs, attacked during the summer of 1956, began in the middle of July, 1957. Beetles emerged not only on warm days when they could immediately take to flight, but also during colder weather (60° F or below) when they were incapable of flying, and suffered the hazards of a period of possibly several days on the log surface or on the ground before weather conditions became suitable for flight.

A study has been made of the variation in the state of the reproductive system throughout the life of the beetle. It was shown that the egg-laying potential increases as the gallery system becomes more extensive.

A series of experiments was carried out to discover whether larvae could be reared on an artificial diet prepared from cultures of ambrosia fungi. The latter were grown on a liquid medium, recovered by filtration, washed free from medium and deposited on filter paper as a fungal mat. Pieces of this mat were presented to larvae maintained under sterile conditions in small glass or

"Perspex" chambers placed in large glass bottles containing a weak glycerine solution to maintain a high humidity. Larvae gained in weight when feeding on two of the fungi used and on mixtures of fungi, but lost weight when fed on other fungi. All larvae died after periods ranging from a few days to three months when fed on these artificial diets. In order to complete their development it appears that the larvae may require a particular mixture of fungal species or that the fungal diet has to be supplemented by finely divided wood. Further feeding experiments have been planned, but the difficulty of obtaining adequate numbers of larvae precludes a large-scale experiment.

A supply of newly emerged beetles has enabled a study of the carriage of fungi by the insects to be undertaken. Fungi recovered from the beetles were shown to be the same as those consistently isolated from their tunnels.

Work continues on the morphology and physiology of fungi cultured from tunnels and beetles. The normal tunnel flora appears to comprise four species of fungi, but others such as *Graphium* and *Ceratocystis* often appear in parts of the gallery where browsing by the insects is not taking place. Two of the regularly occurring fungi are yeast-like and one of these can be assigned to the genus *Endomycopsis*, but not to known species. One of the fungi which in young culture has a *Cephalosporium* growth form bears some resemblance to *Leptographium lundbergii* but is quite distinct from this species and has not yet been identified. The fourth fungus has been cultured from single chlamydospores and is also unidentified, but bears some resemblance in culture to a *Sporotricum*. Data on the growth rates, carbon and nitrogen assimilation and fermentation properties of the fungi have also been obtained.

The nitrogen extraction apparatus modified after Graham and Werner[25] has been used to extract volatile substances from samples taken from oak logs and stumps, and it is planned to carry out analyses of extracts in an attempt to find out whether there are consistent differences between extracts from attractive and non-attractive wood. Experiments on the reaction of beetles to extract were carried out using an apparatus in which a stream of air to which extract could be added was drawn past the beetles. The beetles showed a tendency to move against the airstream whether extract was present of not, but no correlation was found between the presence of extract and any reaction of the beetles. Similarly, in experiments with the apparatus using fresh chippings from an attractive log, and in field tests with extract, no response could be elicited from the beetles.

At a site in Tubney Wood near Oxford, further felling of oak took place during the winter 1956–57 and the opportunity was taken to make cultures from stumps at intervals after felling, to determine whether any correlation existed between the presence of fungi or bacteria in the wood and subsequent incidence of attack by the oak pinhole borer. The results of this work are not complete, but a yeast was found in most stumps which were subsequently proved to be attractive, but was absent from most of the unattractive stumps.

Other Ambrosia Beetles and Fungi

Isolations have been made from imported tropical hardwoods showing ambrosia beetle attack and the fungi compared with those associated with *Platypus cylindrus*

An interesting case was encountered of attack by two unidentified species of ambrosia beetle in a standing tree of *Baikiaea insignis* var. *minor* from Uganda where subsequent growth of the tree had completely occluded the

insect tunnels and the damage was revealed only on peeling the log. Heavy staining associated with the tunnels was found to be due not to fungus but to the deposition of gums on the wood cells as a wound reaction.

Investigations in West Africa

The work of the West African Timber Borer Research Unit in Ghana has been continued in co-operation with the Laboratory, and a report of its activities for the period from 1953–55 has been published[26]. An officer recently appointed to the Unit spent four months at the Laboratory for training before taking up his duties in Ghana.

DEATH-WATCH BEETLE (*Xestobium rufovillosum*)

Damage by the death-watch beetle in buildings is most severe in built-in timbers or in timber in ill-ventilated situations and progress of attack is much more rapid in the presence of old fungal decay. Precise data are lacking on the effect of differences in moisture content upon the rate of larval growth. An experiment has been set up during the year to investigate this aspect of the moisture relations of the death-watch beetle, using oak sapwood decayed to a known loss in weight by the white rot *Phellinus cryptarum*, with which the death-watch beetle is often associated in buildings.

H.M.S. Victory

In view of the good results obtained by three annual fumigation treatments (1954–56) of H.M.S. *Victory* with methyl bromide, for the destruction of the death-watch beetle, it was recommended in a joint report by the Forest Products Research Laboratory and the Pest Infestation Laboratory, that a fourth fumigation of the ship should not be carried out in 1957. This recommendation was accepted by the Victory Advisory Technical Committee.

The number of death-watch beetles collected on the ship during the emergence period, April to June, 1957, was only 72 as compared with 230 in 1956. This further drop in numbers in emergence records since 1953 (see last year's Report, p. 40) confirms previous indications that the extent of penetration of methyl bromide into the timbers has been sufficient to destroy at least some of the larvae which might have completed their development and emerged as beetles, and justifies the postponement of a further fumigation.

Sirex WOOD-WASPS

A quantity of infested Norway spruce and larch obtained in 1956 has yielded a supply of wood-wasps during the summer of 1957. These have been used to infest freshly felled logs of Norway spruce to provide material required for investigations with fumigants and insecticides.

A paper on the action taken in the United Kingdom to meet the Australian *Sirex* quarantine regulations was prepared for the Seventh Commonwealth Forestry Conference in Australia and New Zealand, 1957[27].

TOXICITY OF METHYL BROMIDE TO WOOD-BORING INSECTS

Laboratory experiments have been continued in co-operation with the Pest Infestation Laboratory, and examination of death-watch beetle material treated in 1956 at various dosages, expressed as concentration-time products, (mg h/l) has been completed. The results may be summarized as follows:

Adults

Following work in 1955 when lethal dosages were determined, further experiments were designed to investigate the effect of sub-lethal treatments on the length of life and the egg-laying capacity of the insects. As the beetles died without egg-laying the work has been repeated.

Eggs

The hatching of eggs 14–28 days old was prevented at a dosage of 50 mg h/l. This work has been repeated, using eggs of two age groups, 1–8 and 30–32 days. Examination of the material is not yet complete.

First-stage Larvae

Treatment of decayed oak sapwood, containing first-stage larvae, at dosages up to 63 mg h/l failed to give 100 per cent mortality. Material has been prepared for further treatments at higher dosages.

LABORATORY TESTS OF WOOD PRESERVATIVES AND INSECTICIDES

Death-watch Beetle

Further tests have been carried out with a number of materials to ascertain their value for the prevention of attack by this insect. Of the materials used, 5 per cent pentachlorophenol with 5 per cent trixylenyl phosphate in white spirit and 0·5 and 0·1 per cent dieldrin or lindane in white spirit prevented egg-laying or hatching of eggs. Five per cent aqueous solution of sodium pentachlorophenate and 5 per cent pentachlorophenol with 7 per cent dehydrated castor oil failed to prevent both egg-laying and hatching.

Powder-post Beetle, Lyctus brunneus

Tests with various formulations of pentachlorophenol for the prevention of attack by this insect have been continued. Five per cent solutions of pentachlorophenol in white spirit made up with either trixylenyl phosphate or dehydrated castor oil failed to give complete protection to English oak sapwood when applied as a one-minute dip. The attack in treated samples was, however, not as extensive as in untreated controls.

A test to re-investigate the preservative properties of orthodichlorobenzene has been completed and confirms previous indications that this insecticide, with excellent penetrating powers, has no lasting effect and little preservative value[28].

Contact Insecticides

Initial tests have been carried out with deposits of dieldrin and lindane applied to filter papers to ascertain their effect on the length of life and egg-laying capacity of the common furniture and death-watch beetles. The initial effect of lindane was greater than that of dieldrin and it has been shown that death-watch beetles laid viable eggs after 24 hours' contact with dieldrin deposits of 0·04 mg/sq. cm and below. After the same period of exposure to lindane-treated papers, deposits of 0·04 and 0·02 mg/sq. cm prevented egg-laying but eggs were laid at 0·004 mg/sq. cm.

Similar tests with the common furniture beetle showed this insect to be more susceptible than the death-watch beetle to both insecticides. After an exposure period of three hours no eggs were laid by beetles which had been in

contact with all concentrations of lindane, whereas eggs were laid by beetles after contact with dieldrin deposits of 0·02 and 0·004 mg/sq. cm: no eggs were laid after contact with deposits of 0·04 mg/sq. cm.

After two weeks' storage the dieldrin deposit of 0·04 mg/sq. cm was still effective in preventing egg-laying by beetles after three hours' contact with the treated papers but contact with all concentrations of lindane failed to prevent egg-laying.

Insecticidal Smokes

Investigations have continued on the use of insecticidal smokes for the destruction of *Lyctus* and common furniture beetles after emergence. Previous work with smokes based on DDT and BHC has shown that residual deposits are comparatively short lived. Further tests have been undertaken with a smoke containing dieldrin and lindane to ascertain the duration of the insecticidal activity of deposits on various surfaces in a treated room. The results with *Lyctus* beetles show that deposits remained effective on horizontal under surfaces for five weeks, vertical surfaces for 15 weeks and horizontal upper surfaces for 20 weeks. Emergence of *Lyctus brunneus* from infested wood exposed to this insecticidal smoke was not completely prevented but eggs were not laid when beetles emerging through such treated surfaces were placed on untreated wood. Similar results were obtained with plywood attacked by the common furniture beetle when a lindane/dieldrin smoke was used. A lindane/DDT smoke failed to prevent emergence and subsequent egg-laying by this insect.

DESTRUCTION OF WOOD-BORING INSECTS BY RADIATION TREATMENTS

Gamma Rays

In continuation of work in co-operation with the Radiation Chemistry Group and the Technological Irradiation Group of the Atomic Energy Research Establishment, Harwell, of which a summary of results has been published[29], further laboratory experiments have been carried out during the year to determine the dosages needed to sterilize adults or to inhibit development at different stages in the life-cycle of the common furniture, death-watch and *Lyctus* bettles. The following is a brief summary of the work in hand.

Common Furniture Beetle. Information has been obtained on the emergence and fertility of beetles derived from irradiated larvae and new experiments have been set up to obtain additional data on the effect of radiation on mature and immature adults, eggs, pupae and naturally infested birch plywood. The effect on egg-laying and fertility of crossing irradiated with non-irradiated beetles is being determined.

Death-watch Beetle. In extension of experiments carried out in 1956, the effect of radiation at dosages varying between 2000 and 10 000 roentgens (r) on egg-laying and hatching is being ascertained. Treatment was applied to immature beetles in December, 1956, about half-way through their normal period of hibernation, for comparison with mature adults irradiated in April, 1956, shortly before emergence took place. No evidence was obtained that irradiation affects the duration of life of the beetles during the normal emergence period. Results again indicate that most eggs laid by beetles irradiated at dosages between 8000 and 10 000 r failed to hatch, but further work is required to determine more precisely the minimum effective dosage.

An experiment was carried out to investigate differences in resistance of males and females to irradiation treatments. Beetles irradiated in December

were mated in March with untreated controls, and data obtained on egg-laying and hatching. Preliminary results show that untreated females mated with irradiated males laid more eggs than irradiated females mated with untreated males, but fewer hatched. From the few data at present available there are indications that males are slightly less resistant to irradiation than females, but further studies are required.

Lyctus *Powder-post Beetles*. Further experiments carried out with *Lyctus brunneus* reared at 25° C and 75 per cent relative humidity have confirmed that irradiation at a low dose rate (50 r/min) is at least as effective as a high rate (1085 r/min) in inhibiting development of partly grown larvae. Confirmatory evidence has been obtained that reduced fertility following irradiation is inherited as far as the first generation. Investigations are being continued into the second generation. Work is in hand to determine the effect of radiation on larvae at different stages of development and there are indications that very young larvae are rather less resistant. Since all investigations has so far been carried out with culture material bred at 25° C and 75 per cent relative humidity, an experiment is planned using insects from naturally infested material out of doors.

Infra-Red Rays

Experiments have continued on the sterilization of insect-infested wood by means of infra-red heating, but it has not yet been possible to specify treatments suitable for timber of different thicknesses or attacked by different wood-boring insects. It has been shown that $\frac{3}{8}$-in. obeche plywood infested by *Lyctus* powder-post beetles can be sterilized by treatments during which a minimum temperature of 55° C is obtained on the under-surface of the material (see last year's Report, p. 43). A similar treatment applied to $\frac{3}{4}$-in. oak floor blocks infested by this insect failed to destroy all larvae within the wood. On the other hand, birch plywood infested by the common furniture beetle was completely sterilized by treatment, during which a minimum temperature of 60° C was obtained on the under-surface. Further work is required before the use of infra-red ray treatments for the destruction of wood-boring insects can be considered in practice.

ADVISORY WORK IN ENTOMOLOGY

The Laboratory has again been asked to report on the extent of activity of the death-watch beetle in buildings of national interest, including the Round Tower, Windsor Castle; King's College Chapel, Cambridge; and Westminster Hall, in co-operation with the Ministry of Works Architect-in-Charge, and to advise on methods of treatment.

Eight inspections of outside properties were undertaken and 831 enquiries dealt with by letter during the year.

CHEMISTRY

WOOD POLYSACCHARIDES

The Hemicelluloses of Beech

Investigations on beech hemicelluloses described in last year's Report (p. 44) are being continued. The mixture of uronic and aldobiuronic acids obtained by acid hydrolysis of alkali-extracted beechwood has been shown, by fractionation on a column of IR4B resin (formate form)[30], to be even more complex than was originally supposed. At least sixteen distinct acids were detected.

Beechwood was extracted successively with 0·1N-, N-, and 17·5 per cent sodium hydroxide under nitrogen, and at each stage a portion of the residue was removed, washed free of alkali and hydrolysed with acid. The mixtures of uronic and aldobiuronic acids so produced were examined on the chromatogram. No appreciable difference in pattern was observed between the acids obtained from untreated wood and from wood extracted with 0·1N alkali. Treatment with stronger alkali, however, appeared to remove progressively four of the acid components. Furthermore, hydrolysis of a sample of hemicellulose A yielded, among other products, a mixture of these four acids. The main component has already been identified[31] as 2-*O*-(4-*O*-methyl-α-*D*-glucopyruronosyl)-*D*-xylose, but the structures of the others, present only in small amount, have yet to be determined. On the present evidence it cannot be decided whether these different aldobiuronic acids are derived from a single polysaccharide or from a mixture.

Attempts have been made to fractionate hemicellulose A through its copper complex, but without success.

A further hemicellulose preparation has been isolated from beechwood in a yield of about 2 per cent. This was obtained by addition of ethanol to a N-sodium hydroxide extract from which hemicellulose A had previously been removed by precipitation with acid. This more soluble fraction yielded, on hydrolysis, a mixture of sugars in which xylose predominated, together with a mixture of acidic materials.

The water-soluble polysaccharides in beech have also been examined. Extractive-free beechwood was covered with cold water and the mixture left, with occasional shaking, for three days. The aqueous extract was separated and evaporated to small volume and the water-soluble polysaccharide was precipitated by additon of ethanol. After purification by reprecipitation the product was dried to a brown powder (yield 0·03 per cent). Hydrolysis yielded galactose, glucose, mannose, arabinose, xylose and rhamnose, identified chromatographically. No other neutral sugars appeared to be present, and only one aldobiuronic acid could be detected on the chromatogram in any quantity. This material had a similar R_G value to 2-*O*-(4-*O*-methyl-*D*-glucopyruronosyl)-*D*-xylose.

Glucomannan from Sitka Spruce

The polysaccharide material containing glucose and mannose residues, which was isolated from Sitka spruce and described in the Report for 1953 (p. 43), has been studied further at the University of Edinburgh and a joint paper has been published[32]. The results of these investigations showed that the polysaccharide material contained at least two essentially linear components, a β-1:4-linked glucan and β-1:4-linked glucomannan, while the possibility that a mannan was also present could not be excluded on the evidence available.

WOOD EXTRACTIVES

Indian Rosewood (Dalbergia latifolia)

A further quantity of the crystalline substance previously isolated (Report for 1955, p. 43) from the light petroleum extract has been prepared, and investigations into its structure are being continued. Analysis and molecular-weight determinations showed this phenolic material to have the formula $C_{17}H_{18}O_4$, and the presence of two methoxyl groups was demonstrated, while

no C-methyl residues could be detected. Two free hydroxyl groups were indicated by the formation of a diacetate and a dimethyl ether. All attempts to prepare a crystalline benzoyl derivative were unsuccessful. Preliminary tests gave evidence of some degree of unsaturation in the molecule.

East African Mulberry (Morus lactea)

The work on dihydromorin has now been completed, and a paper[33] published.

As mentioned in last year's Report (p. 45), it was shown that dihydromorin could not be prepared by alkaline dithionite reduction of morin. It has since been found that attempted reduction of datiscetin (5:7:2′-trihydroxy-flavonol) also failed to yield any dihydro-derivative. From these results it would appear that resistance to reduction is associated with some steric effect of the 2′-hydroxyl group which is common to the two flavonols.

A sample of dihydromorin was examined at the Low Temperature Research Station, Cambridge, and they reported that it had no appreciable antioxidant activity. This finding is in accord with the behaviour predicted for a compound of this structure.

Baikiaea insignis *var.* minor

The sample investigated had a very wide sapwood with only a small core of dark-coloured, sharply differentiated heartwood. Attempts to prepare baikiain[34] from the heartwood were unsuccessful. This result is of considerable interest, as baikiain was first isolated some time previously from the heartwood of the related *Baikiaea plurijuga* ("Rhodesian teak") in good yield. The latter work was described in the Report for 1951 (p. 45).

Red Meranti (Shorea leprosula)

A crystalline substance isolated from this timber by extraction with alcohol (see Report for 1954, p. 40) has been examined further at the University of Edinburgh and was shown to be identical with the compound bergenin, which occurs in the roots of *Bergenia crassifolia*. A joint paper on this subject has been published[35].

DEVELOPMENT OF ACIDITY IN WOOD UNDER MOIST CONDITIONS

Investigation of the liberation of acetic acid from several wood species under damp conditions has been continued. Samples of Douglas fir stored at 48° C have now been under observation for a period of two years and the progressive development of acidity in these has been followed by determining the amount of free acid present after various periods of time. After 18 months the rate of liberation of acid had decreased very considerably and appeared to be becoming asymptotic. The amount at that time was equivalent to 1·4 per cent by weight of the dry wood sample. This figure is almost equal to the total amount of acetic acid which could, theoretically, be obtained from the acetyl groups originally present in the wood as determined by analysis.

Samples of seven other species included in the same series of experiments all gave erratic results and many of them showed obvious signs of contamination with some organism.

Mycological examination of these samples showed them to be infected by certain thermophilic fungi which flourish at the temperature chosen for the experiment and which do not thrive in wood at normal service temperatures.

The effect of this infection was either to inhibit completely the liberation of acetic acid observed in uncontaminated samples or to neutralize it as it is formed.

In order to find a method of preventing the growth of these fungi, a new series of birch samples, inoculated with a spore suspension containing the organisms, was prepared. Various fungicidal chemicals were included for comparison and the samples were maintained at 48° C for periods up to ten weeks. Samples containing no fungicide showed no gain in free acid and the fungi remained active throughout. Those containing mercuric chloride, to the extent of one part per 1000 parts total moisture, liberated acid progressively at a rate directly proportional to time of storage and similar to that previously observed in uncontaminated samples of birch. The inclusion of mercuric chloride did not appear to have affected the course of the chemical reaction involved. It is hoped that its use will enable further investigations to be made over a wide range of temperature without the complications due to chance infection by various organisms.

CORROSION OF CADMIUM-PLATED METAL BY WOOD AND GLUES

Investigations on the corrosion of cadmium-plated parts by volatile components arising from wood have been extended to include plywood and wood-glue assemblies incorporating a number of different synthetic-resin glues. It has now been established that, in addition to the corrosive effect of some woods, previously reported, volatile components from these glues can also be very corrosive to cadmium plate, particularly under damp conditions. In a series of experiments in which cadmium-plated steel samples were exposed at 48° C and 100 per cent relative humidity to the atmosphere over plywoods made from two wood species using four commercial hot-pressed plywood glues, all the plywood samples were more corrosive than the corresponding wood controls without glue. Two urea/formaldehyde (U/F) glues caused severe corrosion during a period of eight weeks, while a liquid phenol/formaldehyde (P/F) and a dry film P/F resin produced only slight corrosion. In another series eleven commercial cold-setting assembly glues were used with one wood. Of these, eight were U/F resins, one was a P/F, one a resorcinol/formaldehyde (R/F), and one was a mixed syrup containing both P/F and R/F resins. Among the U/F glued samples, results after eight weeks' exposure varied from no corrosion to complete destruction of the cadmium plate with heavy rusting of the steel beneath. Volatile acidic substances released during the curing and ageing of the glues appeared to be the chief corrosive agents, assisted in some cases by formaldehyde liberated by decomposition of the resin. The extreme variability in the corrosive effect of these glues, all made from the same type of resin, appeared to arise from the different hardening mechanisms favoured by the various makers. No generalizations could, therefore, be made with regard to the corrosive effect to be expected from any one type of resin.

These results are of interest to Service departments in connexion with the design and construction of cases of wood or plywood for storage of military equipment.

PRODUCTION OF HARDBOARD FROM COLONIAL TIMBERS

Further trials have been carried out with morabukea chips defibred in a laboratory Asplund Defibrator in order to determine the optimum conditions for refining the pulp to the degree necessary for making boards of satisfactory

strength. These involved the use of several different plate designs and settings in the Sprout Waldron disc refiner. Best results were obtained with plates of a non-cutting profile set to give a nominal clearance of 0·005 to 0·007 in. The coarse fibre was fed to the refiner at a uniform rate and in a semi-dry condition, water being added in the mill so that pulp left the plates as a slurry of 5 to 6 per cent consistency. Under these conditions a steady rate of power consumption was maintained in the mill and this could be controlled within limits by the rate of feed.

A standardized technique, based on these experiments, was also applied to four Malayan timbers from which satisfactory boards had already been made by a semi-chemical process, in order to compare the merits of the two types of process. Marked differences in behaviour between the different species under similar conditions were shown by the results of these trials. Morabukea, for instance, with a bulk density of 65 lb/cu. ft, gave a pulp which could absorb power at a high level during refining treatment without breaking down to give excessive amounts of "fines". The increase in drainage time produced in the pulp was proportional over a wide range to the power consumed. Balau, on the other hand, with a similar bulk density, yielded pulp which broke down to fines very readily at comparatively low power consumption without any proportionate increase in drainage time. These differences were reflected to a marked degree in the strength of the boards it was possible to make from the two species.

A paper[36] was presented to the Seventh British Commonwealth Forestry Conference in Australia in which the results obtained on several tropical hardwoods by both the Defibrator and the semi-chemical processes were compared.

ADVISORY WORK IN CHEMISTRY

The number of enquiries dealt with by letter was 207, representing a small increase over previous years, and visitors totalled 55. The topics arising most frequently are stains and discolorations on wood and plywood, corrosion of metals in association with wood, bleaching of wood, selection and treatment of timber for specific purposes, and the manufacture of pulp and board products.

Two instances have been seen of staining of goods packed in bitumenized Kraft paper in wooden cases. In both cases the wood in contact with the paper was found to be cedar (*Cedrus* sp.), and the staining was shown to be due to softening of the bitumen by the volatile oil from the cedar wood. A somewhat similar enquiry concerned rotary brushes in which the bristles were set in holes in the brush head (of keruing) filled with pitch. The pitch had been softened by the oleoresin in keruing, with the result that the bristles fell out.

PHYSICS

WOOD-WATER RELATIONSHIPS

Waterlogging of Wood

The experiments on waterlogging of wood, mentioned in last year's Report (p. 47), have been continued. Samples, measuring 10 × 2 × 0·5 cm in the longitudinal, radial and tangential directions respectively, of the 17 timbers shown in Fig. 4 were evacuated, flooded with water and, after releasing the vacuum, left for 16 hours, thus exposing the submerged samples to normal atmospheric

pressure. The specimens were then re-weighed, measured and replaced under water. The measurements were repeated after 1 year's immersion. All of the timbers took up more water on continued immersion. Most increases in moisture content were very slight, but a few timbers showed appreciable or even large changes, e.g. gaboon, from 70 to 230 per cent.

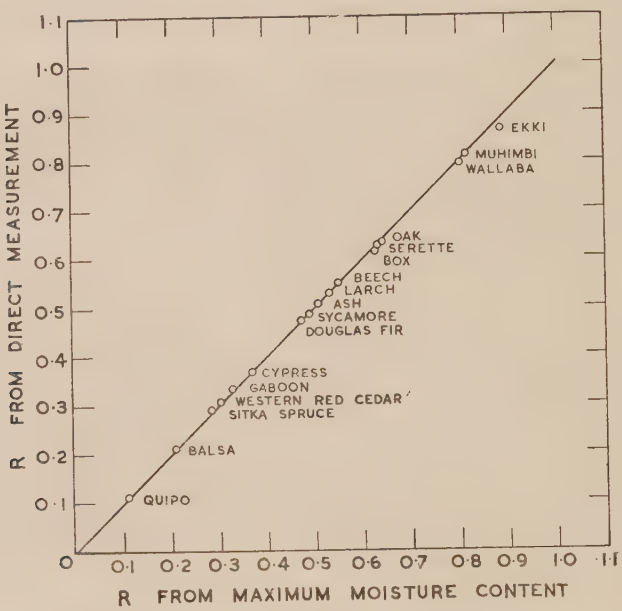


Fig. 4. Comparison of densities obtained from direct measurement and from maximum moisture content

The interest of these experiments lies in the fact that the maximum moisture content m (g/g) can be expressed in terms of basic density R (dry weight/waterlogged volume) and the density of wood substance S as follows:

$$m = \frac{1}{R} - \frac{1}{S}.$$

Assuming that the density of wood substance is 1·5 for all species, the equation becomes

$$m = \frac{1}{R} - \frac{1}{1{\cdot}5},$$

and

$$R = 1/(m + 0{\cdot}667).$$

This equation offers the possibility of determining basic density simply by measuring the maximum moisture content, thus rendering volume measurements unnecessary[37] and facilitating density determinations on irregularly shaped specimens. In Fig. 4, the values of R, calculated from the moisture contents after 1 year's immersion, are plotted against the values determined by direct weighing and measurement. The agreement between the two sets of results is

very close; the mean ration (R from direct measurement/R from maximum moisture content) for the 17 timbers is 1·005 and the coefficient of variation (100 × standard deviation/mean) is 1·5 per cent.

Experiments were also carried out to see what period was required for the maximum moisture content to be reached. These experiments were carried out on different samples of the timbers used in the main experiment. The techniques were identical, but the weights of the specimens were taken more frequently and the experiment was discontinued after 51 days. The curves of moisture content against time for 12 of the timbers are shown in Fig. 5. The observations on those timbers which showed appreciable change in moisture content are plotted as crosses, and the remainder as circles. In many of the timbers the change was negligible, but the uptake in the heavier timbers, and in one or two of medium density, tended to be slow. The slowest of all was gaboon, which after 51 days was still about 30 per cent short of its calculated maximum moisture content. Thus when using the maximum moisture content method for estimating basic density, the period of immersion must be determined carefully. With most species, a few days is adequate, in agreement with the results of Smith[38], but for other species, a period of weeks or even months may be required. With gaboon, the period of immersion would probably be so long as to make the method impracticable for this species.

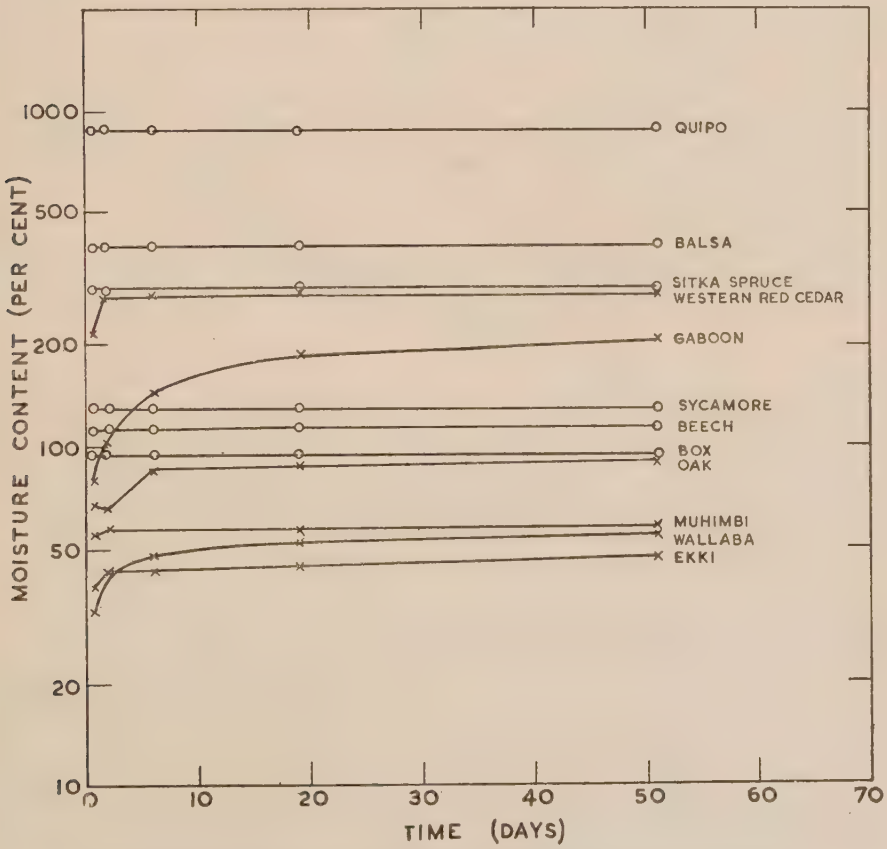


Fig. 5. Moisture content of timbers as affected by time of immersion

Effect of Gamma Rays on the Hygroscopicity of Wood

With the co-operation of the Technological Irradiation Group, Isotope Division, of the Atomic Energy Research Establishment at Harwell, Sitka spruce specimens were exposed to gamma rays from cobalt-60 to dosage levels of 1, 10 and 100 million rad. (1 rad. is approximately 1·1 roentgens). After irradiation the equilibrium moisture content curves were determined, and the adsorption curves for the control and 100 million rad. samples are shown in Fig. 6. The curves for doses of 1 and 10 million rad. are not given, but they were practically indistinguishable from the control. Fig. 6 shows that there is a small reduction in hygroscopicity with the $10^{(8)}$ rad. dose. It therefore appears that very heavy doses of radiation are required to affect the hygroscopicity (and possibly other physical properties also) and that below 10 million rad. the effect is negligible. This dose is some 150 times the maximum dose mentioned by Bletchly and Fisher[29] in work on the control of wood-boring insects by gamma rays. If this method of control is developed for use in the field, its effect on the wood is evidently likely to be small.

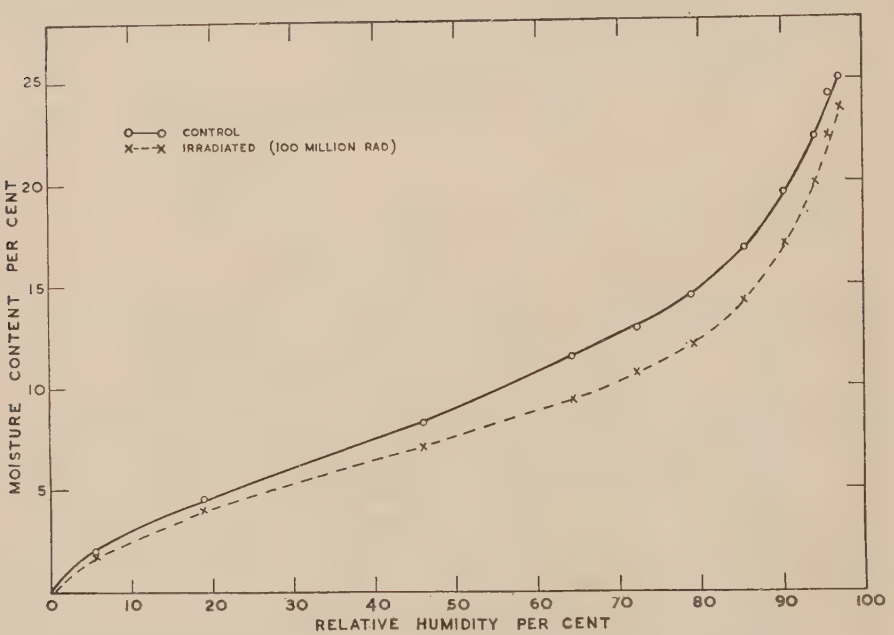


Fig. 6. Effect of gamma rays on equilibrium moisture content of wood

Effect of Sodium Chloride and other Additives on the Hygroscopicity of Wood

A relative humidity of 75 per cent represents a critical point for the wood-sodium chloride-water system, because a saturated solution of sodium chloride is in equilibrium with this relative humidity. Measurements of the equilibrium moisture content (e.m.c.) of pure sodium chloride have shown zero moisture uptake below 75 per cent relative humidity, but at this humidity the moisture content increases without rise in relative humidity until the salt is dissolved to give a saturated solution. Further uptake of moisture raises the relative humidity until at infinite dilution the humidity reaches 100 per cent.

At relative humidities below 75 per cent, introduction of wood into this sodium chloride-water system should give an e.m.c. curve similar to that for wood alone. At and above 75 per cent relative humidity the e.m.c. should depend on the amount of sodium chloride present in the system.

Measurements previously mentioned in last year's Report (p. 49) on Scots pine containing 3 per cent sodium chloride have shown that the experimental results are in agreement with theory at and above 75 per cent relative humidity. At lower humidities, however, the e.m.c. is slightly higher at all stages than that of wood alone. Further measurements on Scots pine containing 11 per cent sodium chloride give similar e.m.c. figures, the increase in e.m.c. from zero humidity to about 60 per cent relative humidity being approximately equal to the increase for Scots pine containing 3 per cent sodium chloride. At the higher salt content, however, the e.m.c. rises earlier and more steeply from 60 per cent relative humidity onwards.

Reduction to sawdust of samples of Scots pine untreated and containing 3 per cent and 11 per cent sodium chloride gave results similar to those obtained for the solid wood.

Small discs of each of the three specimens of Scots pine, untreated, and containing 3 and 11 per cent sodium chloride were continuously extracted with cold water for one week. Measurements of the e.m.c. curves showed no appreciable difference between treated and untreated after extraction and also little difference from the e.m.c. of the unextracted untreated wood. Any effects produced by adding sodium chloride to wood can therefore be removed by leaching out the salt, and the wood thus restored to its original state.

Measurements have also been carried out on beech containing a fire retardant following complaints from the Ministry of Supply about mould growth on hardwood ammunition boxes treated with this retardant. The results showed the e.m.c. to be higher at all humidities than on untreated wood, although in this instance, no sudden breaks were observed in the curves. The increase in e.m.c. was such that at 80 per cent relative humidity, the e.m.c. was about 20 per cent, and any further increase in humidity would therefore bring the wood to a moisture content favourable for the development of moulds.

Diffusion of Water Vapour

Further analysis of the rate of uptake of moisture by wood conditioned at one relative humidity and exposed at another has shown that it should be possible to obtain information on the variation of diffusion coefficient for water vapour with moisture content by this method. However, the results of earlier experiments, although showing the method to be a promising one, were not extensive enough for a complete picture of the variation to be obtained, and further experiments are now in progress to enable a more thorough test of the method to be made. Experiments have also been started on the rate of movement of water vapour through discs of redwood drawn from consignments of different origin with the object of finding the variability of rate of movement within a single species.

ELASTIC AND ALLIED PROPERTIES

In the non-destructive vibration testing of wood, the two quantities which can be measured are the modulus of elasticity (E), and the logarithmic decrement (d). The former determines the frequency of vibration of a specimen of given size and density, whereas the latter determines the tendency of the

vibrations to die away naturally. Another technique, which has not so far been applied extensively to wood, consists in passing a pulse of ultra-sonic energy through the material and measuring the velocity and attenuation of the pulse. However, the velocity and attenuation are quite simply related to E and d respectively, so the two methods are not independent, but the pulse propagation method may enable the experiments to be carried out at a frequency considerably higher than those applicable to vibration experiments.

In view of the possible use of the pulse propagation method on wood, and of other suggested applications of ultrasonics, calculations have been made of the velocity of extensional and shear waves in wood, as affected by orientation relative to the principal directions (longitudinal, radial and tangential). In order to carry out the calculations at all, simplifying assumptions had to be introduced, but polar diagrams have now been prepared which show approximately the velocities with which the various types of waves are propagated in all directions in a typical hardwood and softwood.

ADVISORY WORK IN PHYSICS

Replies to enquiries have included the following subjects: thermal conductivity and insulation; electrical resistance; detection of metal in wood; absorption of gamma rays, application of statistical methods, effect of nuclear radiations, density of beech as related to neutron absorption.

EXTERNAL RELATIONS

During the year a total of 8101 cu. ft of timber was brought into the Laboratory, which is 1456 cu. ft less than in 1956. Of the total quantity, there were 2611 cu. ft of imported hardwoods, 1584 cu. ft of imported softwoods, 1587 cu. ft of home-grown hardwoods and 2319 cu. ft of home-grown softwoods.

GENERAL TESTING

During the year six reports on imported timbers under test were completed:

Light red seraya .	*Shorea smithiana*
Light red seraya .	*Shorea parvifolia*
Kapur . . .	*Dryobalanops lanceolata*
Keruing. . .	*Dipterocarpus* sp.
Yellow seraya .	*Shorea faguetiana*
Pillarwood . .	*Cassipourea malosana*

The first five timbers were sent in by the North Borneo Forest Service in co-operation with the trade, and pillarwood was supplied by, and tested at the request of, the Tanganyika Forest Department.

Two reports were completed and results sent to the Forestry Commission on two small consignments of home-grown roble (*Nothofagus obliqua*) and one consignment of home-grown rauli (*Nothofagus procera*).

TIMBER QUALITY IN RELATION TO SILVICULTURE

Seven consignments of thinnings of home-grown softwoods from Forestry Commission plantations were tested during the year under the project for investigating the quality of the timber in relation to the site and soil. The species tested were Scots pine and Norway spruce both in full-scale consignments, Douglas fir, in one consignment of five trees and one of three trees, and Serbian spruce, in one consignment of five trees.

The Scots pine was obtained from Farnborough, Hampshire, and Banchory, Kincardineshire, and the trees were 68 and 70 years old respectively; the strength, density and working properties of this species appear to vary little over the country although the results of grading have been significantly affected by the condition of the knots in the timber.

The two parcels of Norway spruce, from Inverliever Forest, Argyllshire, and Coed-y-Brenin Forest, North Wales, were respectively the second and third consignments of the species so far tested.

One parcel of 48-year-old Douglas fir was obtained from Thetford Forest, Norfolk, to complete the survey of this species over the country. Only five trees were tested. As remarkably little variation has been observed in the timber from all areas it is intended to produce a combined report upon the species from the seven consignments tested. Later in the year three trees of 72-year-old Douglas fir were brought in from Reelig Forest, Inverness-shire, and examined in relation to the previous consignments as a potential forecast for a further twenty-five years' growth. It appears that density and strength increase with increasing age at any one height until the tree is about twenty-five years old at that height; rate of growth is of somewhat lesser importance.

The Serbian spruce, *Picea omorika*, which is a European close relative of the Sitka spruce, came from Barcaldine Forest, Argyllshire; it was slower grown and slightly denser and stronger than Sitka spruce from a similar area.

Nine progress reports were issued during the year upon previously tested consignments of Sitka spruce (one), Douglas fir (three), Japanese larch (one), Scots pine (three) and western hemlock (one).

GRADING OF HOME-GROWN HARDWOODS

A committee was set up in May to consider drawing up grading rules for home-grown hardwoods. The committee consisted of representatives of the Forestry Commission, merchants, manufacturers and architects.

It has been decided to draw up the rules on a defect system rather than a "cutting" system, and a draft has been drawn up for the members to submit to their associations. The committee's work should be completed early in 1958.

TRADE SURVEYS

The work on trade surveys has been continued and intensified during the year. The report has been issued on the use of timber in the sports goods industry and the field work on the use of timber in road vehicles is almost completed. A survey was also undertaken to ascertain the timbers used and the problems arising in the manufacture of vats and filterpresses and in cooperage work. The field work on this survey has been completed and the report is in hand.

VISITS

Contacts with firms using and trading in timber were continued on an increased scale, and altogether 97 were contacted.

VISITORS AND EDUCATION

This part of the Laboratory's work has increased during the year, and it has been necessary to curtail drastically the number of parties coming from the technical colleges.

Technical visitors from wood-using firms and other organizations, totalled 99 representatives, a reduction on last year's total. This was mainly due to the petrol rationing from December to the end of March. The number of visiting parties increased by one, and the total number of persons shown round the Laboratory was 311 against 240 in 1956.

Two official Government delegations visited the Laboratory. One was from China and the other from the Forestry Department of Eire.

Visitors from overseas numbered 83, and they represented 33 countries.

The demand for instruction and courses, usually of short periods of 3 to 5 days has increased. Instruction was given to members of Government departments and laboratories both in the Commonwealth and in foreign countries.

The courses for students from the four universities with a forestry faculty and for timber technology students from the Imperial College took place as usual. Four courses have been held in kiln seasoning, attended by 33 students, and six students have received special training in wood bending.

LECTURES AND EXHIBITIONS

At the request of the Ministry of Works, lectures on wood-boring insects and their control were given at Boston, Lincs., and Ewell, Surrey.

A small portable exhibit was prepared in conjunction with the British Electrical and Allied Industries Research Association to illustrate how the life of creosoted transmission poles can be increased, and premature decay eliminated, by the use of correct treatment. The exhibit has been on show at the Institution of Electrical Engineers and during the year has been to the headquarters of a number of the area boards of the Central Electricity Authority.

ADVISORY WORK IN EXTERNAL RELATIONS

The number of enquiries dealt with by letter was 148.

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F. Y. Henderson,
Director

Forest Products Research Laboratory,
Princes Risborough,
Aylesbury, Bucks.

March, 1958.

APPENDIX I

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

31st *December*, 1957

Director of Forest Products Research: F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: J. Bryan, M.Eng., A.M.I.C.E.
Senior Principal Scientific Officer: P. Harris, B.Sc.(Eng.), A.M.I.Mech.E.
Higher Executive Officer: R. D. Weeks, M.B.E.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge);
E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Senior Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officer: G. L. Franklin.
Assistant Experimental Officer: D. G. Patterson, M.Sc.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, F.Inst.P. (Officer in Charge).
Experimental Officers: E. H. Adams; J. Mc.C. Paton.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, Assoc.I.Mech.E.; D. D. Johnston;
G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Assistant Experimental Officer: R. H. Wynands.
Temporary Assistant Experimental Officer: D. C. Bedding.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officers: A. J. Comben, B.Sc.; W. T. Curry; J. G. Sunley, M.Sc.
Senior Experimental Officer: A. J. Foord.
Experimental Officer: G. R. Brock.
Assistant Experimental Officers: S. A. Covington; Miss W. M. Fogerty; W. T. Hide.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: D. N. R. Smith (Officer in Charge).
Experimental Officers: R. Cockcroft; Miss E. Lee; D. F. Purslow, B.Sc.; L. W. Redding.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officer: R. A. Laidlaw, B.Sc., Ph.D.
Senior Experimental Officer: D. F. Packman, B.E.M.
Experimental Officer: L. C. Pinion, B.Sc.
Temporary Assistant Experimental Officer: G. A. Smith.

SECTION OF MYCOLOGY

Senior Principal Scientific Officer: W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A. (Officer in Charge).
Principal Scientific Officer: J. G. Savory, B.Sc.
Experimental Officer: E. C. Badcock.
Assistant Experimental Officer: Mrs. C. A. Savory, B.Sc.

SECTION OF ENTOMOLOGY

Principal Scientific Officers: R. C. Fisher, B.Sc., Ph.D., F.R.S.E. (Officer in Charge); J. D. Bletchly, B.A., B.Sc., F.R.E.S.
Scientific Officer: M. G. White, M.A., F.R.E.S.
Senior Experimental Officer: E. C. Harris, F.R.E.S.
Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: K. J. S. Walker, M.A.
Senior Experimental Officers: H. J. Endersby; R. Goodchild.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: F. G. O. Pearson, B.Sc. (Officer in Charge).
Senior Experimental Officer: A. V. Thomas, M.Eng.
Experimental Officer: Miss C. Webster.
Assistant Experimental Officer: Miss H. A. Fielding, B.A.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng), M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Experimental Officer: R. W. Hudson.
Assistant Experimental Officer: B. H. Paxton.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip.For. (Officer in Charge).
Experimental Officer: J. A. H. Broughton, B.Sc.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel, Assoc.I.Mech.E.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1957

A. STATIONERY OFFICE PUBLICATIONS

Forest Products Research, 1956.

Handbook of Softwoods.

Bulletins:

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

African mahogany	*Khaya* spp.
Afrormosia	*Afrormosia elata*
Agba	*Gossweilerodendron balsamiferum*
Apple, White star	*Chrysophyllum albidum*
Ash	*Fraxinus excelsior*
Balau	*Shorea* spp.
Balsa	*Ochroma lagopus*
Baltic redwood	*Pinus sylvestris*
Baltic whitewood	*Picea abies*
Beech	*Fagus sylvatica*
Birch	*Betula* spp.
Birch, Finnish	*Betula* spp.
Bosquiea	*Bosquiea phoberos*
Cedar	*Cedrus* spp.
Cedar, Western red	*Thuja plicata*
Ceiba	*Ceiba* spp.
Chestnut, Horse	*Aesculus hippocastanum*
Corsican pine	*Pinus nigra* var. *calabrica*
Douglas fir	*Pseudotsuga taxifolia*
East African mulberry	*Morus lactea*
East African olive	*Olea hochstetteri*
English walnut	*Juglans regia*
European redwood	*Pinus sylvestris*
European spruce	*Picea abies*
European walnut	*Juglans regia*
Finnish birch	*Betula* spp.
Fir, Douglas	*Pseudotsuga taxifolia*
Fir, grand	*Abies grandis*
Fir, Noble	*Abies procera*
Fir, Silver	*Abies alba*
Gaboon	*Aucoumea klaineana*
Grand fir	*Abies grandis*
Greenheart	*Ocotea rodiaei*
Hazel	*Corylus avellana*
Hemlock, Western	*Tsuga heterophylla*
Horse chestnut	*Aesculus hippocastanum*

Indian mulberry	*Morus alba*
Indian rosewood	*Dalbergia latifolia*
Japanese larch	*Larix leptolepis*
Japanese oak	*Quercus* spp.
Kapur	*Dryobalanops lanceolata*
Keruing	*Dipterocarpus* spp.
Larch	*Larix* spp.
Larch, Japanese	*Larix leptolepis*
Lenga	*Nothofagus pumilio*
Light red seraya	*Shorea* spp.
Lime	*Tilia vulgaris*
Mahogany, African	*Khaya* spp.
Morabukea	*Mora gonggrijpii*
Muchenche	*Newtonia buchanani*
Mulberry, East African	*Morus lactea*
Mulberry, Indian	*Morus alba*
New Zealand white pine	*Podocarpus dacrydioides*
Nirre	*Nothofagus antarctica*
Nkobakoba	*Baikiaea insignis* var. *minor*
Noble fir	*Abies procera*
Norway spruce	*Picea abies*
Oak	*Quercus* spp.
Oak, Japanese	*Quercus* spp.
Obeche	*Triplochiton scleroxylon*
Ocote pine	*Pinus oocarpa*
Olive, East African	*Olea hochstetteri*
Pillarwood	*Cassipourea malosana* (syn. *C. elliottii*)
Pine	*Pinus* spp.
Pine, Corsican	*Pinus nigra* var. *calabrica*
Pine, New Zealand white	*Podocarpus dacrydioides*
Pine, Ocote	*Pinus oocarpa*
Pine, Pitch	*Pinus* spp.
Pine, Scots	*Pinus sylvestris*
Pitch pine	*Pinus* spp.
Poplar	*Populus* spp.
Ramin	*Gonystylus* spp.
Rauli	*Nothofagus procera*
Redwood	*Pinus sylvestris*
Redwood, Baltic	*Pinus sylvestris*
Redwood, European	*Pinus sylvestris*
Rhodesian teak	*Baikiaea plurijuga*
Roble	*Nothofagus obliqua*
Rosewood, Indian	*Dalbergia latifolia*

Sapele	*Entandrophragma cylindricum*
Sepetir	*Pseudosindora palustris*
Seraya, Light red	*Shorea* spp.
Seraya, White	*Parashorea malaanonan* var. *tomentella*
Seraya, Yellow	*Shorea faguetiana*
Serbian spruce	*Picea omorika*
Scots pine	*Pinus sylvestris*
Silver fir	*Abies alba*
Sitka spruce	*Picea sitchensis*
Spruce, European	*Picea abies*
Spruce, Norway	*Picea abies*
Spruce, Serbian	*Picea omorika*
Spruce, Sitka	*Picea sitchensis*
Teak	*Tectona grandis*
Teak, Rhodesian	*Baikiaea plurijuga*
Tineo	*Weinmannia trichosperma*
Ulmo	*Eucryphia cordifolia*
Walnut, English	*Juglans regia*
Walnut, European	*Juglans regia*
Western hemlock	*Tsuga heterophylla*
Western red cedar	*Thuja plicata*
White seraya	*Parashorea malaanonan* var. *tomentella*
White star apple	*Chrysophyllum albidum*
Whitewood, Baltic	*Picea abies*
Willow	*Salix* spp.
Yellow seraya	*Shorea faguetiana*

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(72675) Wt 4182/861 K8 6/58 Hw.

Printed and published by
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S.O. Code No. 47-74-0-57